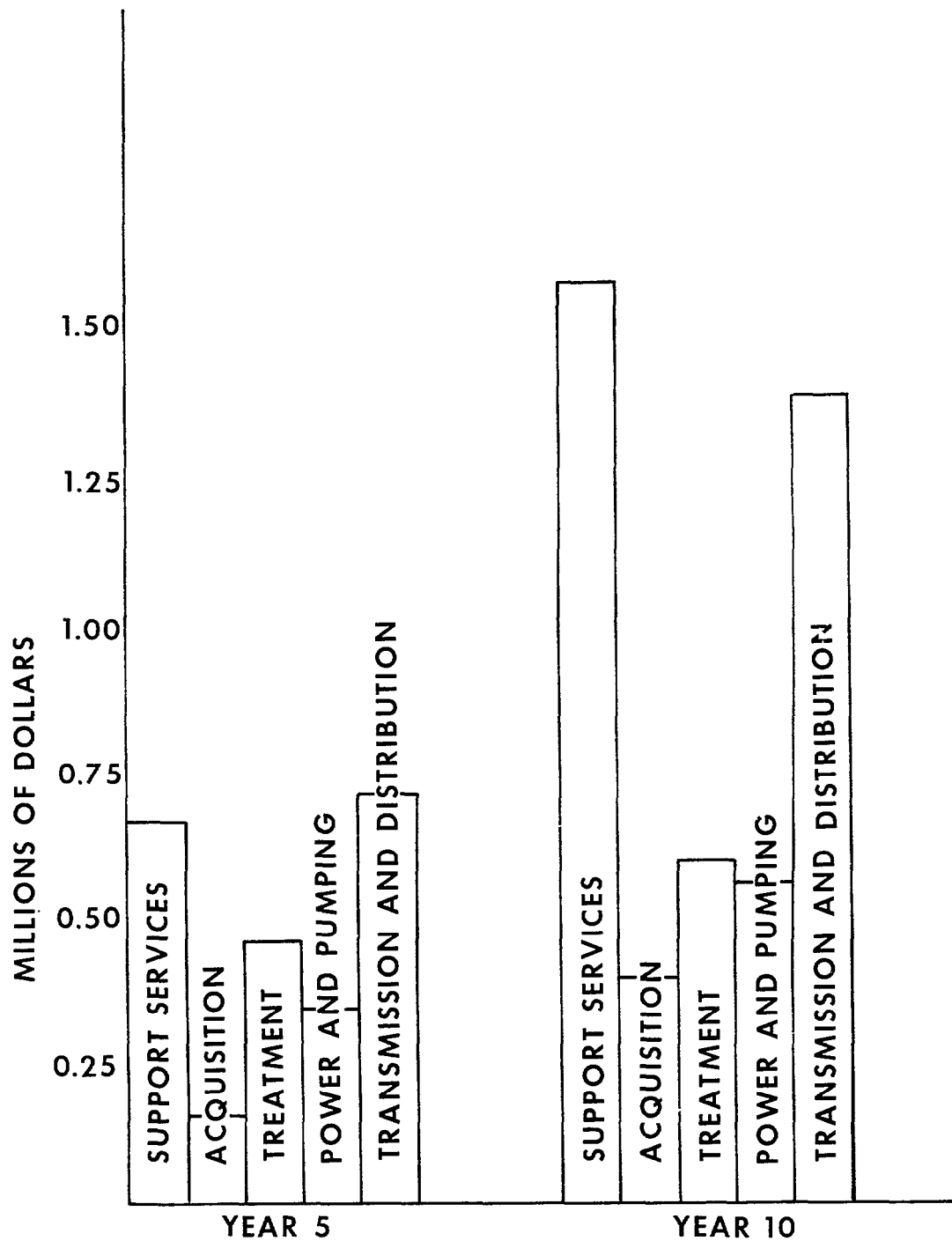


TABLE 13. OPERATING AND CAPITAL EXPENDITURES FOR FAIRFAX COUNTY WATER AUTHORITY

Item	Year									
	1	2	3	4	5	6	7	8	9	10
OPERATING COSTS:										
Support services:										
\$, in millions	-	-	-	-	0.673	1.000	1.253	1.232	1.406	1.548
% of total	-	-	-	-	29.05	34.60	38.82	35.66	35.72	34.94
\$/mil gal	-	-	-	-	45.29	62.43	73.51	70.03	76.00	80.53
Acquisition:										
\$, in millions	-	-	-	-	0.150	0.206	0.250	0.289	0.243	0.387
% of total	-	-	-	-	6.48	7.11	7.73	8.36	6.19	8.74
\$/mil gal	-	-	-	-	10.11	12.84	14.64	16.42	13.15	10.15
77 Power and pumping:										
\$, in millions	-	-	-	-	0.330	0.384	0.409	0.463	0.528	0.526
% of total	-	-	-	-	14.23	13.28	12.65	13.39	13.41	11.87
\$/mil gal	-	-	-	-	22.18	23.97	23.97	26.29	28.53	27.36
Transmission and distribution:										
\$, in millions	-	-	-	-	0.702	0.737	0.743	0.918	1.174	1.386
% of total	-	-	-	-	30.29	25.49	23.01	26.55	29.82	31.26
\$/mil gal	-	-	-	-	47.22	46.00	43.57	52.16	63.45	72.05
Treatment:										
\$, in millions	-	-	-	-	0.462	0.564	0.574	0.555	0.586	0.584
% of total	-	-	-	-	19.93	19.51	17.79	16.04	14.89	13.18
\$/mil gal	-	-	-	-	31.07	35.21	33.69	31.51	31.67	30.37
Total Operating Costs:										
\$, in millions	0.708	0.834	1.096	1.345	2.317	2.891	3.229	3.456	3.938	4.432
\$/mil gal	397.92	402.22	451.57	340.57	155.87	180.45	189.38	196.38	212.80	230.46

TABLE 13 (Continued). OPERATING AND CAPITAL EXPENDITURES FOR FAIRFAX COUNTY WATER AUTHORITY

Item	Year									
	1	2	3	4	5	6	7	8	9	10
CAPITAL COSTS:										
Depreciation										
(\$, in millions)	0.234	0.234	0.241	0.912	1.584	1.584	1.584	1.584	1.584	1.587
Interest										
(\$, in millions)	0.608	0.663	0.663	0.663	4.800	3.401	4.935	4.105	4.060	4.011
Total capital cost										
78 (\$, in millions)	0.842	0.897	0.904	1.575	6.384	4.985	6.519	5.689	5.644	5.598
Total operating and capital cost:										
\$, in millions	1.550	1.782	2.000	2.921	8.701	7.876	9.748	9.146	9.581	10.030
\$/mil gal	871.48	810.36	823.90	739.41	585.29	491.64	571.73	516.74	517.79	521.55



**FIG. 45 OPERATING COSTS FOR FAIRFAX COUNTY WATER UTILITY**

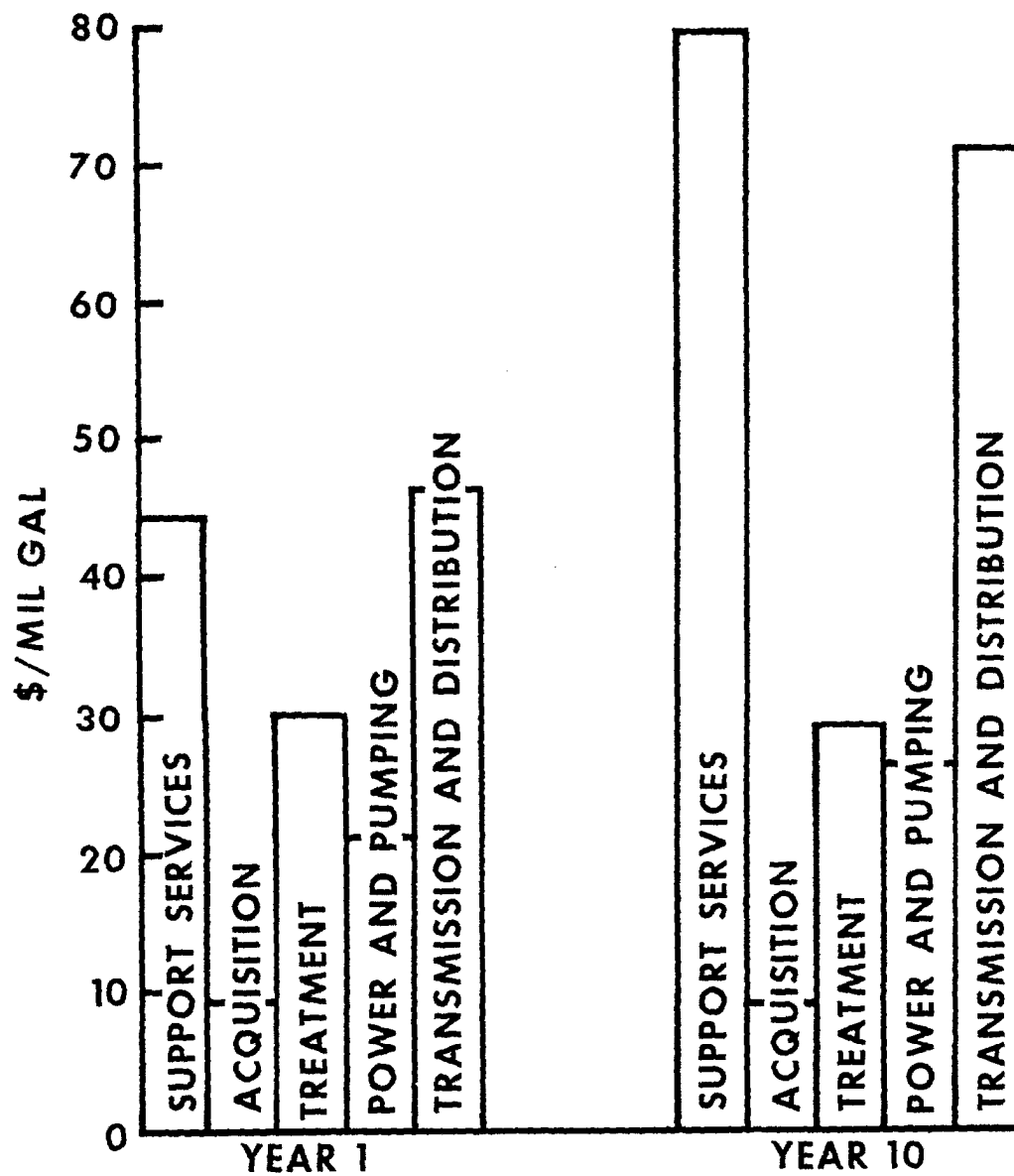


FIG. 46 OPERATING COST IN \$/MIL GAL FOR FAIRFAX WATER UTILITY

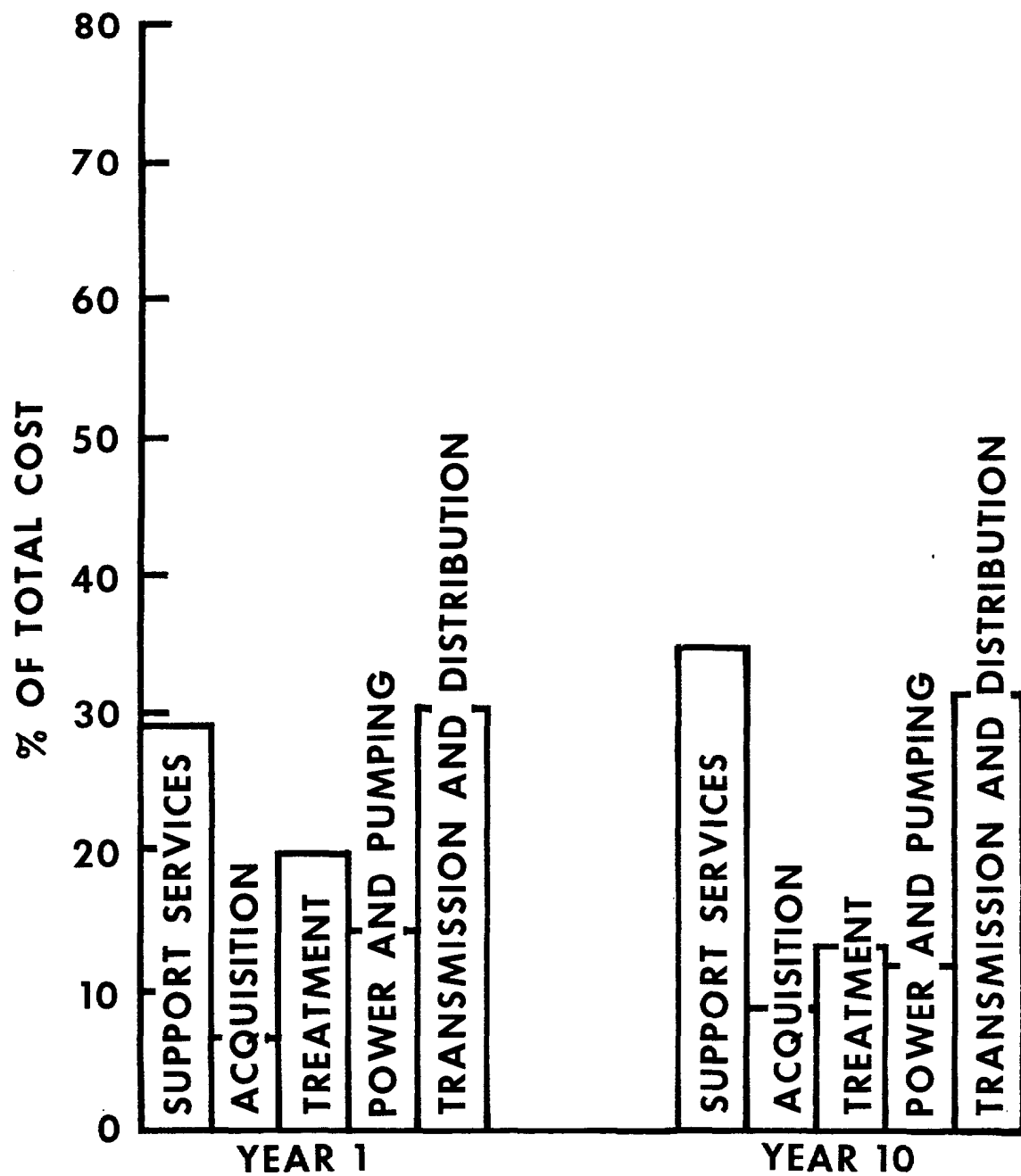
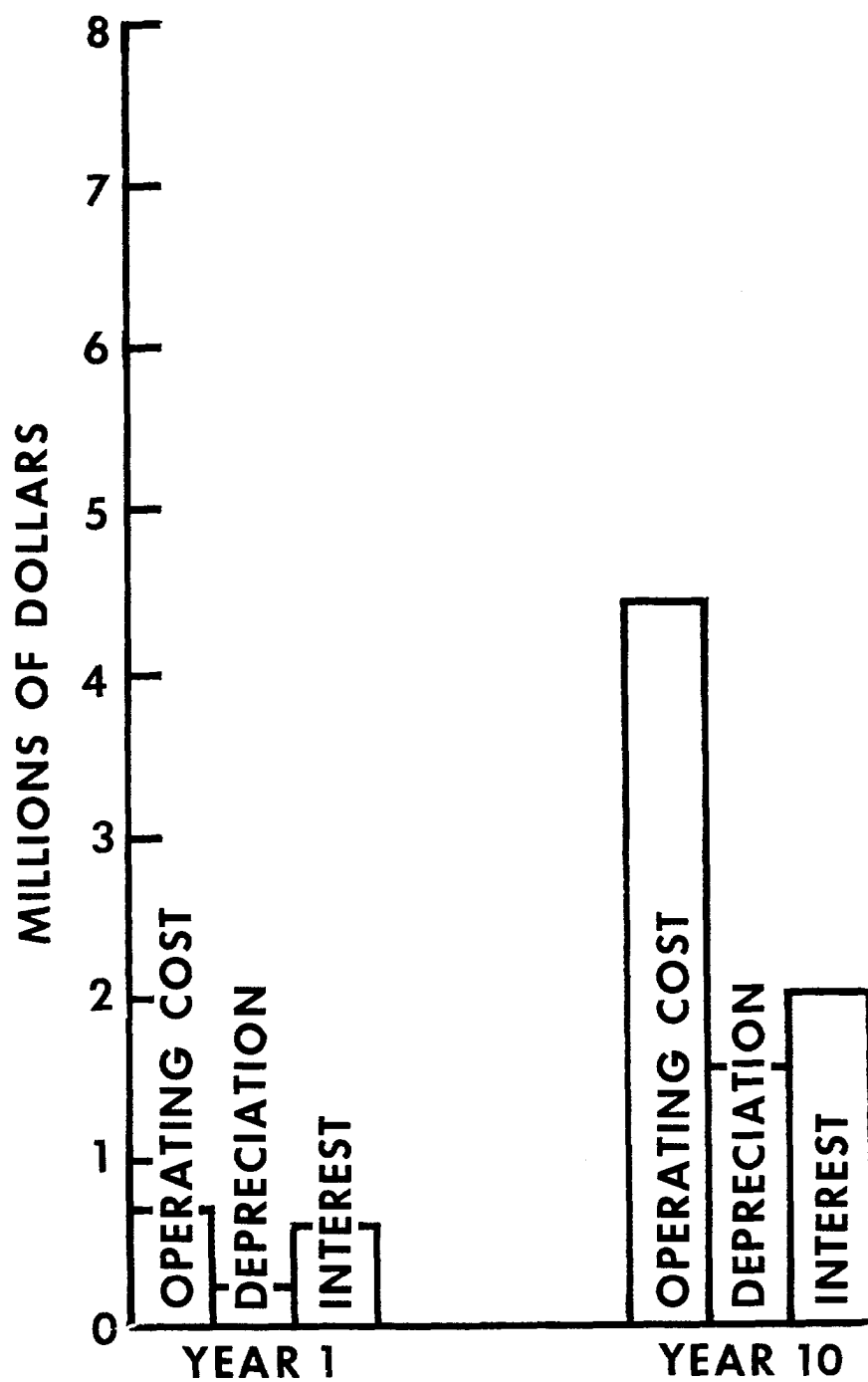


FIG. 47 OPERATING COST AS A PERCENT OF  
TOTAL COST FOR FAIRFAX WATER UTILITY



**FIG. 48 OPERATING AND CAPITAL COSTS FOR FAIRFAX WATER UTILITY**

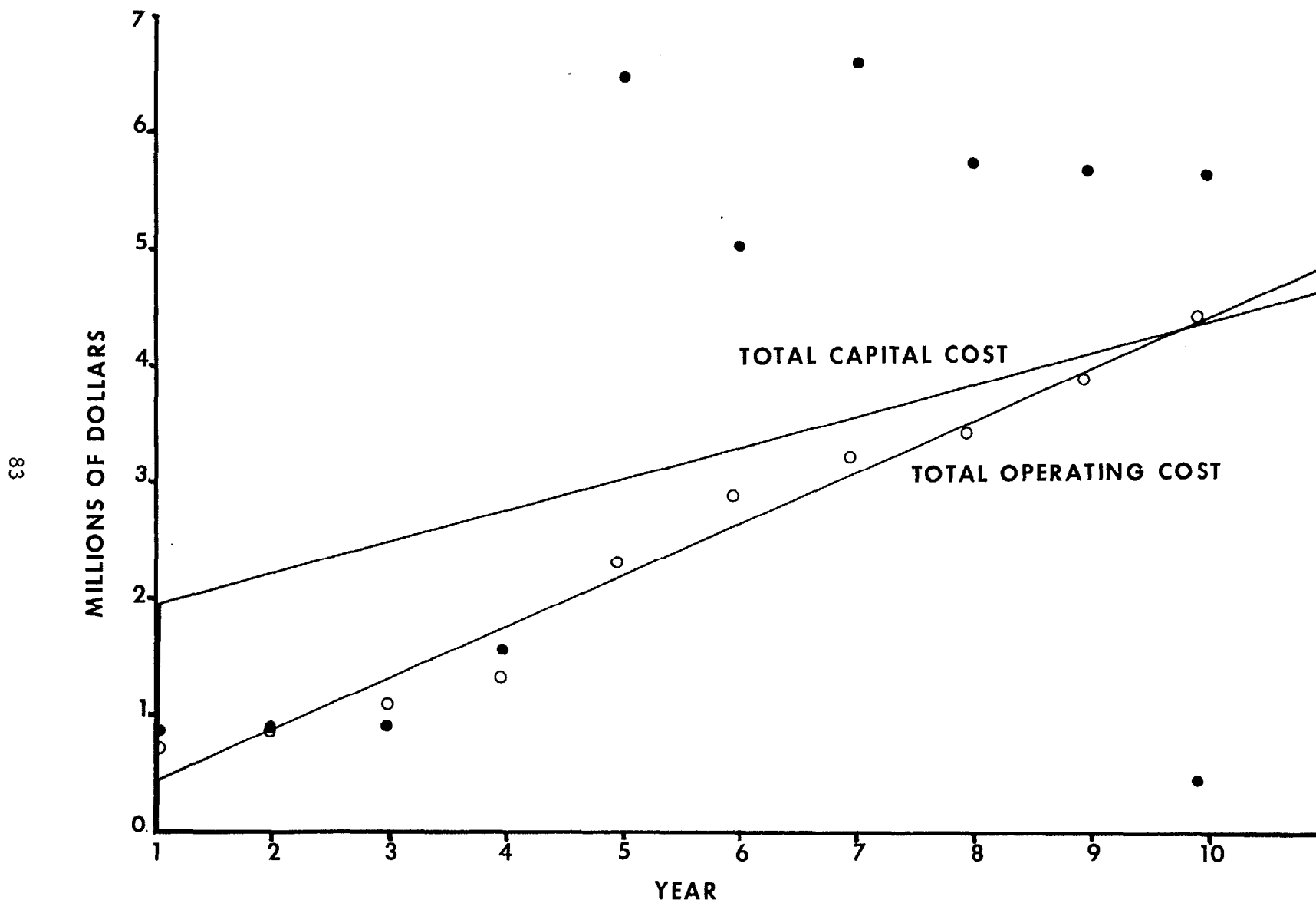


FIG. 49 OPERATING AND CAPITAL EXPENDITURES FOR FAIRFAX WATER AUTHORITY

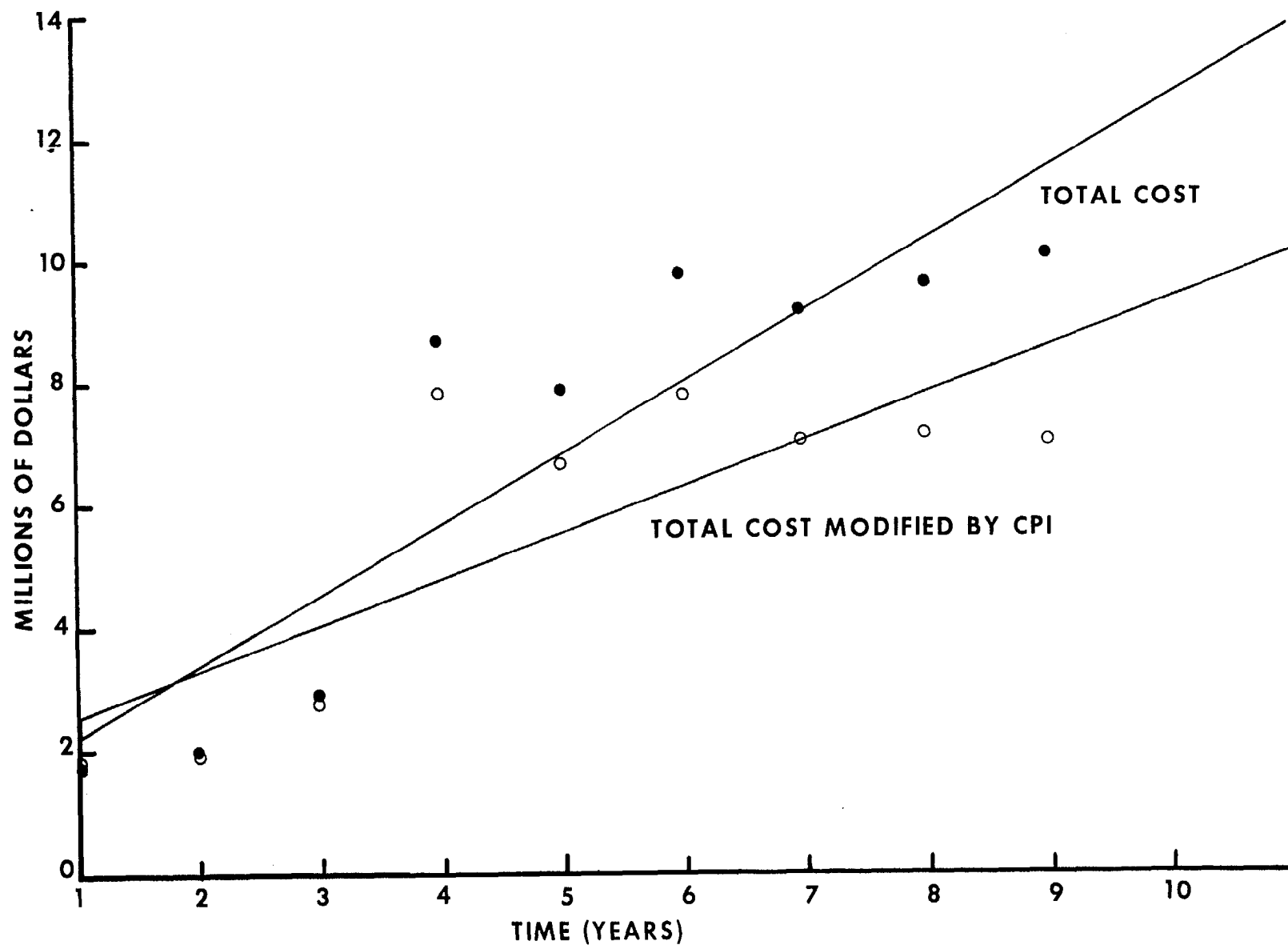


FIG. 50 TOTAL EXPENDITURES FOR FAIRFAX WATER AUTHORITY:  
HISTORICAL AND MODIFIED



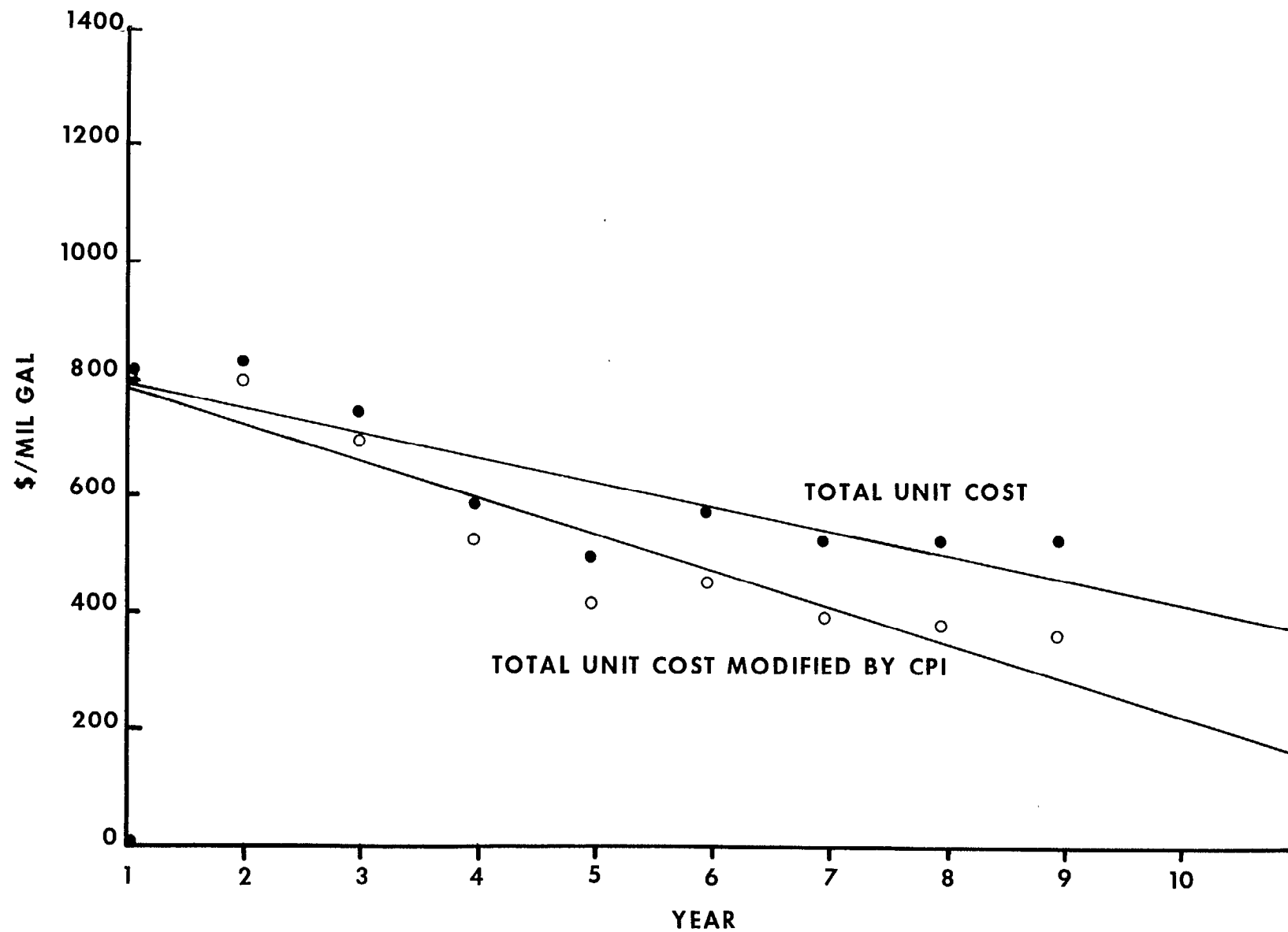


FIG. 51 UNIT COST FOR FAIRFAX WATER AUTHORITY: HISTORICAL AND MODIFIED

Inflationary pressures have caused the unit costs, even when corrected for time by the CPI, to exhibit steady increases.

Cincinnati's distribution system is similar to Kansas City's and allows for a cost versus distance analysis. In Cincinnati, water production has increased steadily, resulting in stabilized unit costs for water. Corrected costs have even decreased slightly. The utility has extensive records for capital investment, and a reproduction cost can be calculated for the waterworks facilities. Results of this analysis demonstrate that over the life of the utility, the value of its capital facilities have increased fivefold. A labor cost and productivity analysis reflects that the increase in labor costs has not been completely balanced by increases in labor productivity.

Dallas is a rapidly growing community with an extensive reservoir system. By continuously expanding the acquisition system and ringing the city with treatment facilities, water shortages have been eliminated, and water costs have been held down.

The Elizabethtown Water Company is an investor-owned utility and as such has a totally different set of problems as compared to publicly-owned utilities. For example, in the last year of analysis, the Elizabethtown utility paid \$4.6 million in real property taxes, or 27% of its total costs.

The Fairfax County Water Authority is rapidly growing by acquiring new customers through the purchase of existing utilities. It represents extreme economies of scale in its capital investments program. Interest costs are much more significant for Fairfax County than for the other utilities because of their recent acquisition of facilities. In the following section, comparisons of these items will be made in more detail.

## SECTION 5

### UTILITY COST COMPARISONS

In this section, cost trends among the various utilities are examined simultaneously.

Figure 52 illustrates the steady increase in revenue-producing water over the 10-year period for the five utilities. The average yearly increase was approximately 5%. Consumption for the Cincinnati, Elizabethtown Water Company, and Kansas City utilities had a lower growth rate than did the consumption for Dallas and the Fairfax County Water Authority.

Dallas' growth is due to demand by the small communities located within Dallas County but outside the city. Should this demand level off, Dallas' water production will probably be similar to that of the Cincinnati, Elizabethtown, and Kansas City utilities.

Water production by the Fairfax County Water Authority has had four- and five-year periods of slightly greater than average growth, separated by a one-year period of very rapid growth because of acquisition of the Alexandria Water Company's source of supply, treatment facilities on Occoquan Creek, and the associated service area. This acquisition occurred during the fourth year of the data analysis period. Growth during the other years is due to smaller additions to the system.

#### cost of Supply

Figure 53 shows unit costs for five utilities. Four of the utilities (Cincinnati, Elizabethtown Water Co., Dallas, and Kansas City) exhibit increases in cost of about 5% a year because of increased prices for power, labor, chemicals, and other items. The Fairfax County Authority unit costs have decreased as a result of the rapid expansion in consumption (Figure 52). Heavy investments in capital in a short time span combined with a rapid expansion in production has reduced costs sharply. Despite these reductions, the cost of Fairfax County water is higher than that of any of the other four utilities.

Figure 54 shows that Elizabethtown Water Co., Cincinnati, and Kansas City have relatively constant operating expenditures as a percent of total cost. For the entire 10-year period, operating cost has been 75% to 85% of total cost. Dallas and Fairfax have maintained lower percentages. In Dallas, 60% to 65% of the costs are operating expenses. In Fairfax, 32% of the expenditures are operating costs. These wide variations occurred as a result of

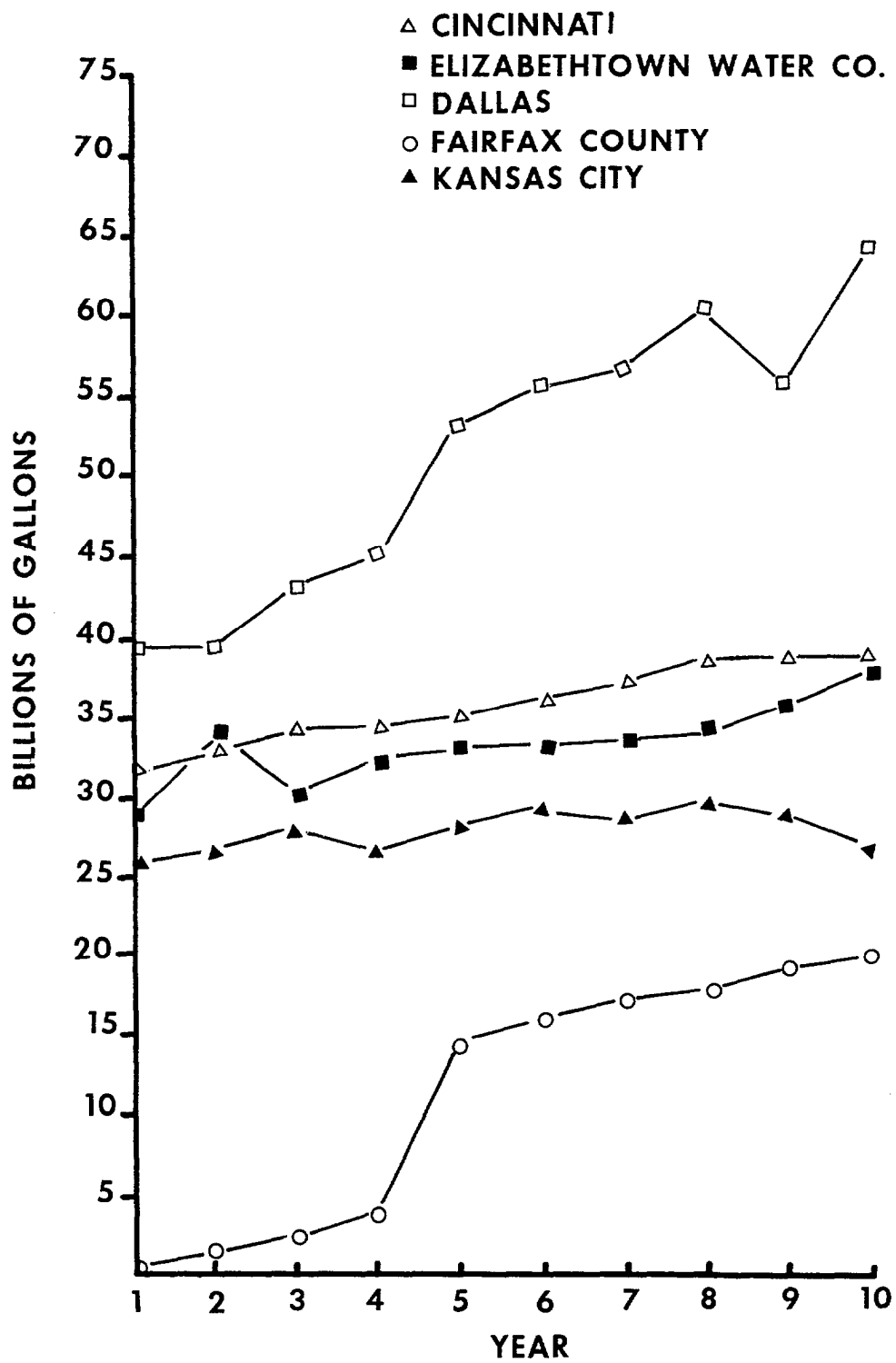


FIG. 52 REVENUE PRODUCING WATER FOR FIVE UTILITIES

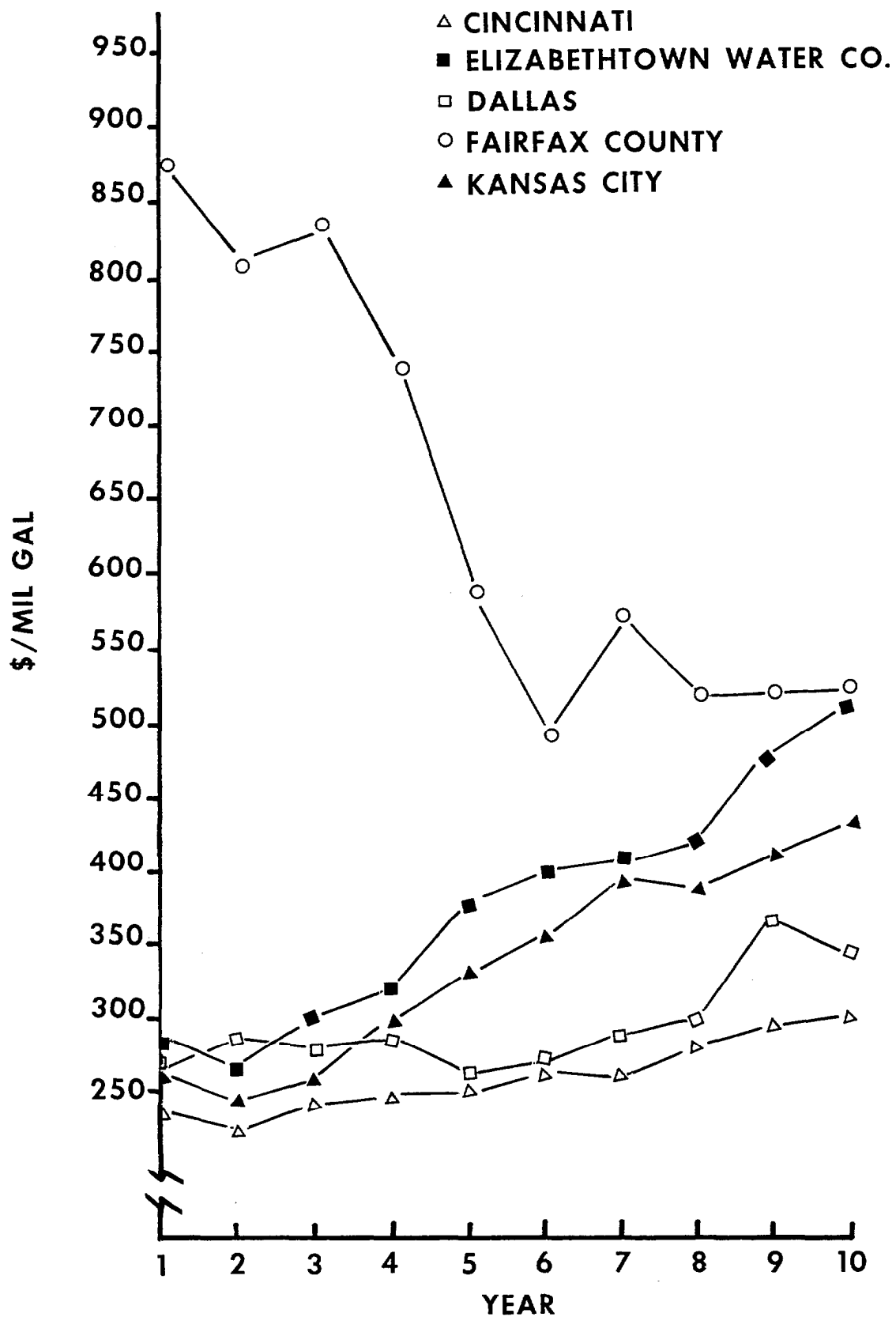


FIG. 53 TOTAL UNIT COST FOR FIVE UTILITIES

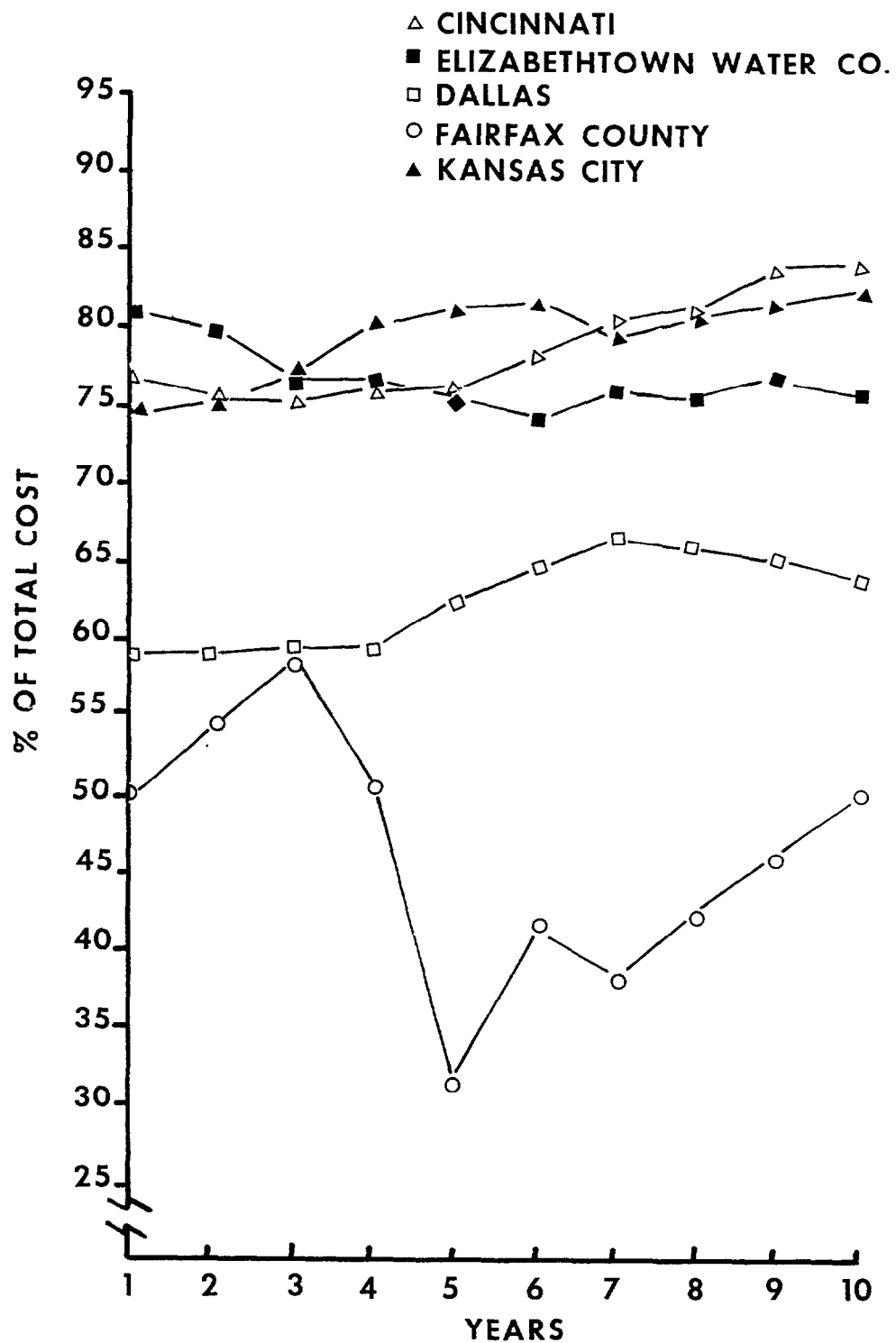


FIG. 54 OPERATING COST AS A PERCENT OF TOTAL COST FOR FIVE UTILITIES

the different characteristics of the utilities studied. Elizabethtown Water Co., Cincinnati, and Kansas City are stable utilities with either no increase or small steady increases in demand for water. Capital investment is primarily utilized for capital improvements of the existing system with limited investment in new facilities. Dallas is a more rapidly growing utility, and Fairfax is a smaller utility that has dramatically increased its water production in 10 years. In order to increase water production at these rates, rapid investment in capital is required thereby reducing the operating expenditures as a percent of total cost. As Dallas and Fairfax County utilities achieve stabilization, their expenditure patterns will be similar to those of the other older utilities.

Figure 55 shows unit costs for treatment. Kansas City, with the highest treatment cost, has also experienced the most rapid increase in unit cost over the 10-year period. Kansas City's treatment plant draws water from the Missouri River. Details of the treatment process, including lime softening, are described in Volume II. Most of the rapid rise in cost is due to increases in chemical and labor costs. Figure 55 shows that Dallas and Elizabethtown have also had substantial increases in treatment costs.

#### Labor-Related Costs

Figures 56, 57, and 58 illustrate labor cost trends for the five water utilities. Labor rates (Figure 56) have increased by about 8% a year. The number of man-hours/mil gal of revenue-producing water (Figure 57) has decreased about 2% a year. Productivity rates vary widely; the Elizabethtown Water Company produces water with fewer than 15 man-hours/mil gal, and the Fairfax County Authority produces water with 22 to 27 man-hours/mil gal; the other utilities require more total man-hours/mil gal.

Figure 58, total payroll costs/mil gal, is a function of the labor rate and productivity. Cincinnati, Elizabethtown, Dallas, and Kansas City show an increase of approximately 6%/year. Fairfax County experienced a sharp decrease during the two years when revenue-producing water increased drastically.

Figure 59 shows support services as a percent of total operating cost, including all administrative, accounting, meter reading and billing, and engineering functions. These costs range from 23% to 45%.

#### First and Last Year Cost Comparisons

Figures 60 and 61 show sharp contrasts in allocation of costs to support services, acquisition, treatment, power and pumping, and transmission and distribution. Fairfax County is not included in these figures because cost data were not available for the full 10-year period.

Figure 60 shows the total dollars increased in every category, with the greatest increase occurring in support services. Figure 61 shows the same breakdown of operating cost categories as a percent of total operating cost. Support services increased as a percent of total, acquisition remained the

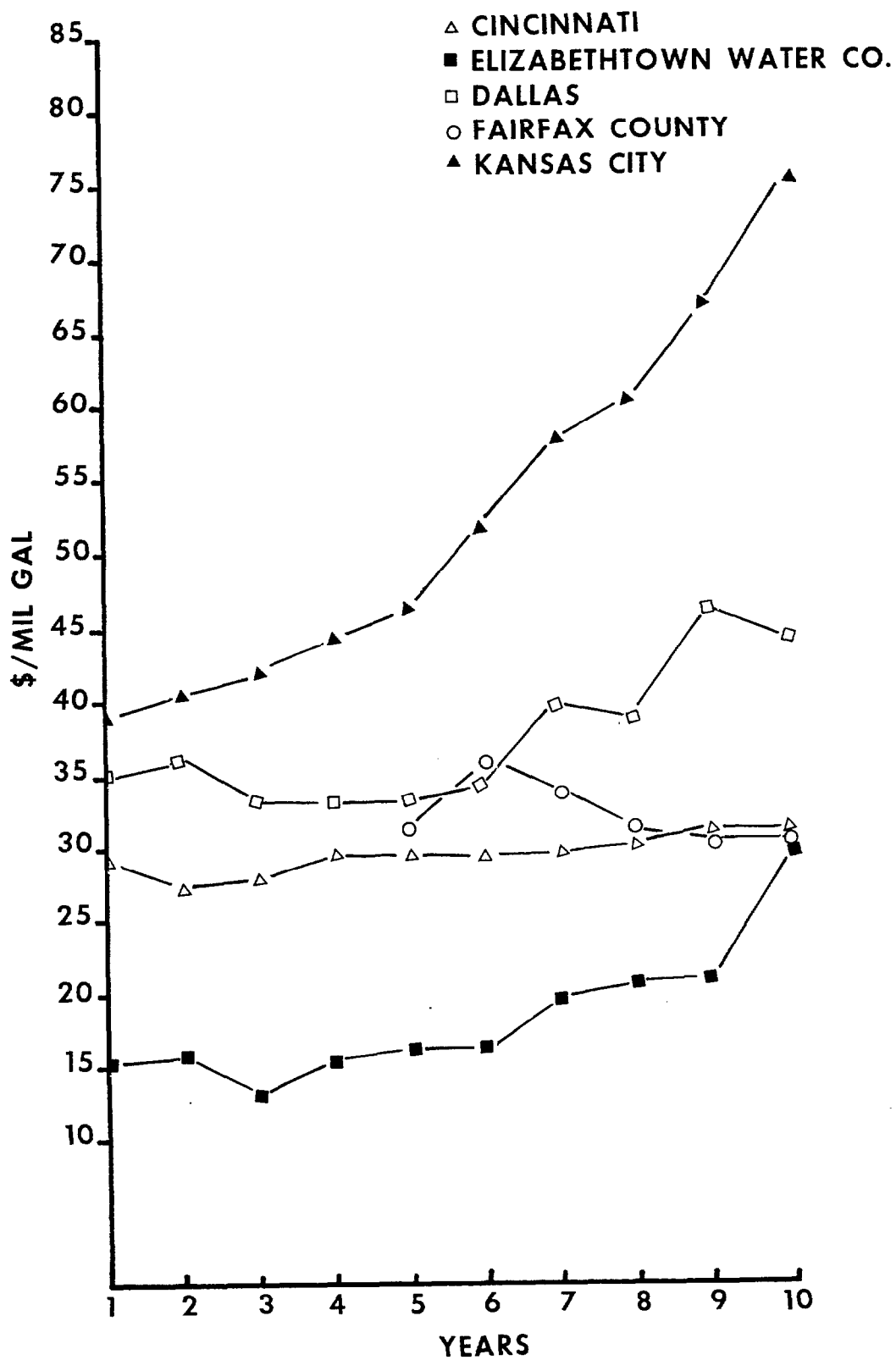


FIG. 55 UNIT TREATMENT COSTS FOR FIVE UTILITIES



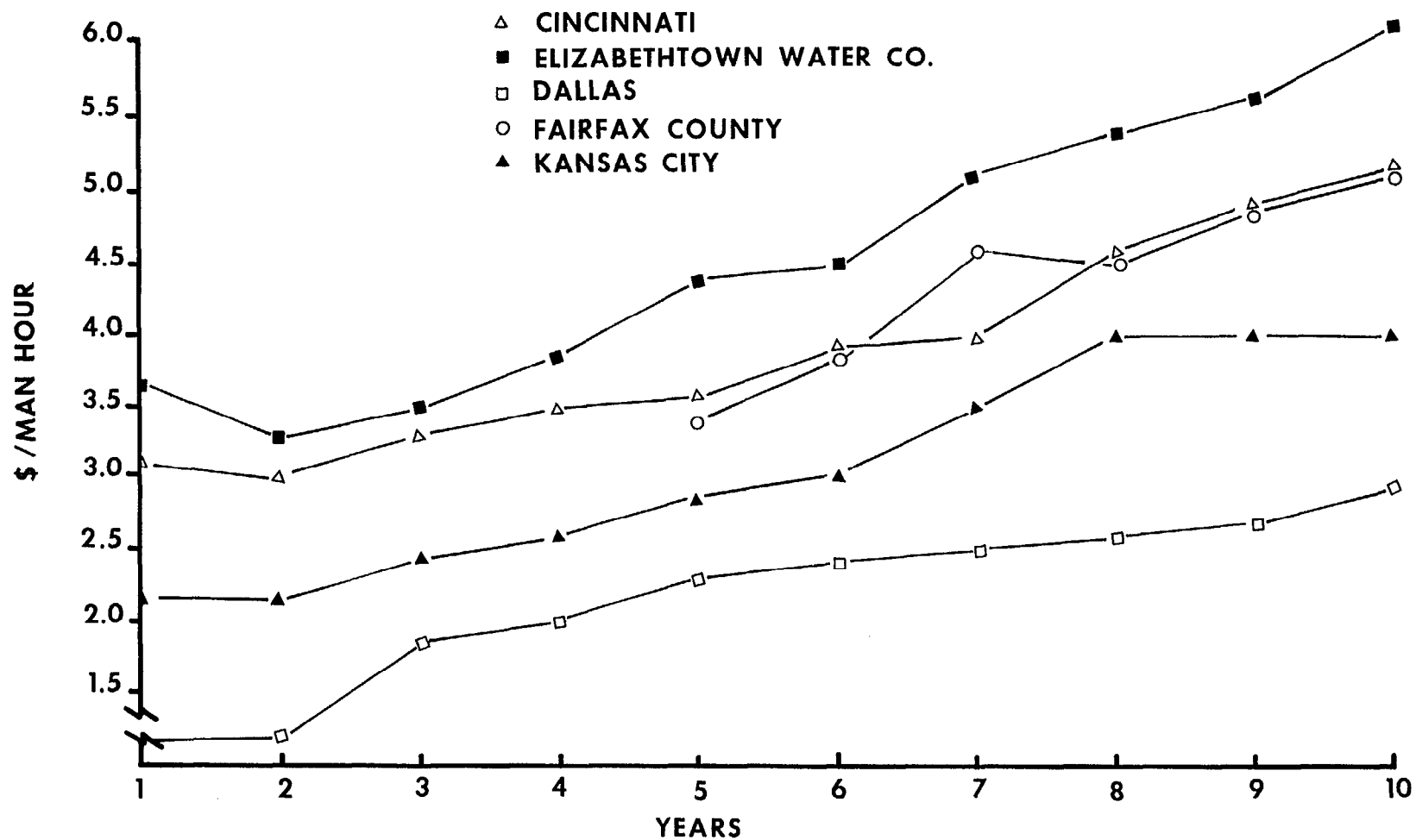


FIG. 56 PAYROLL IN DOLLARS/MAN HOUR FOR FIVE UTILITIES

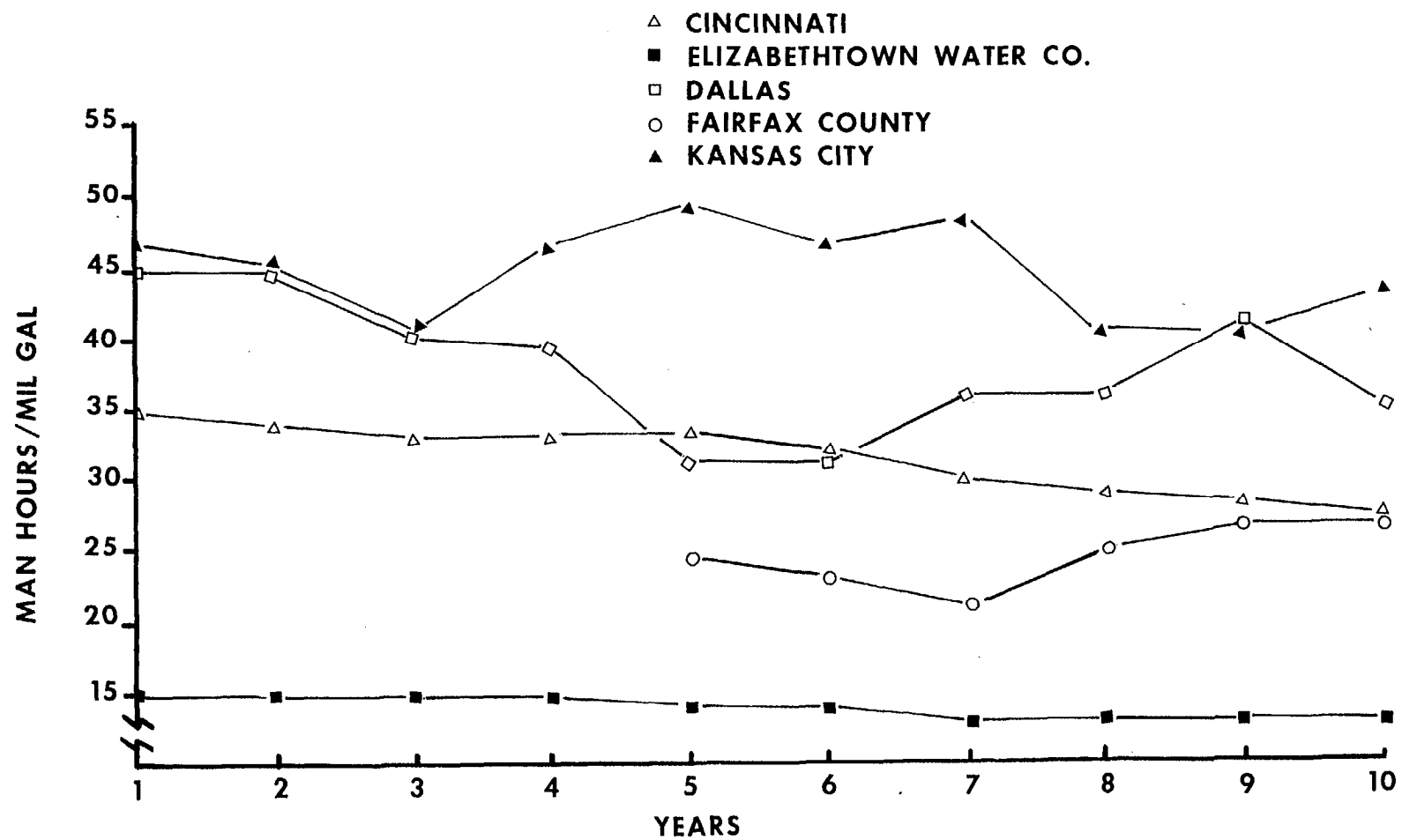


FIG. 57 MANHOURS/MIL GAL FOR FIVE UTILITIES

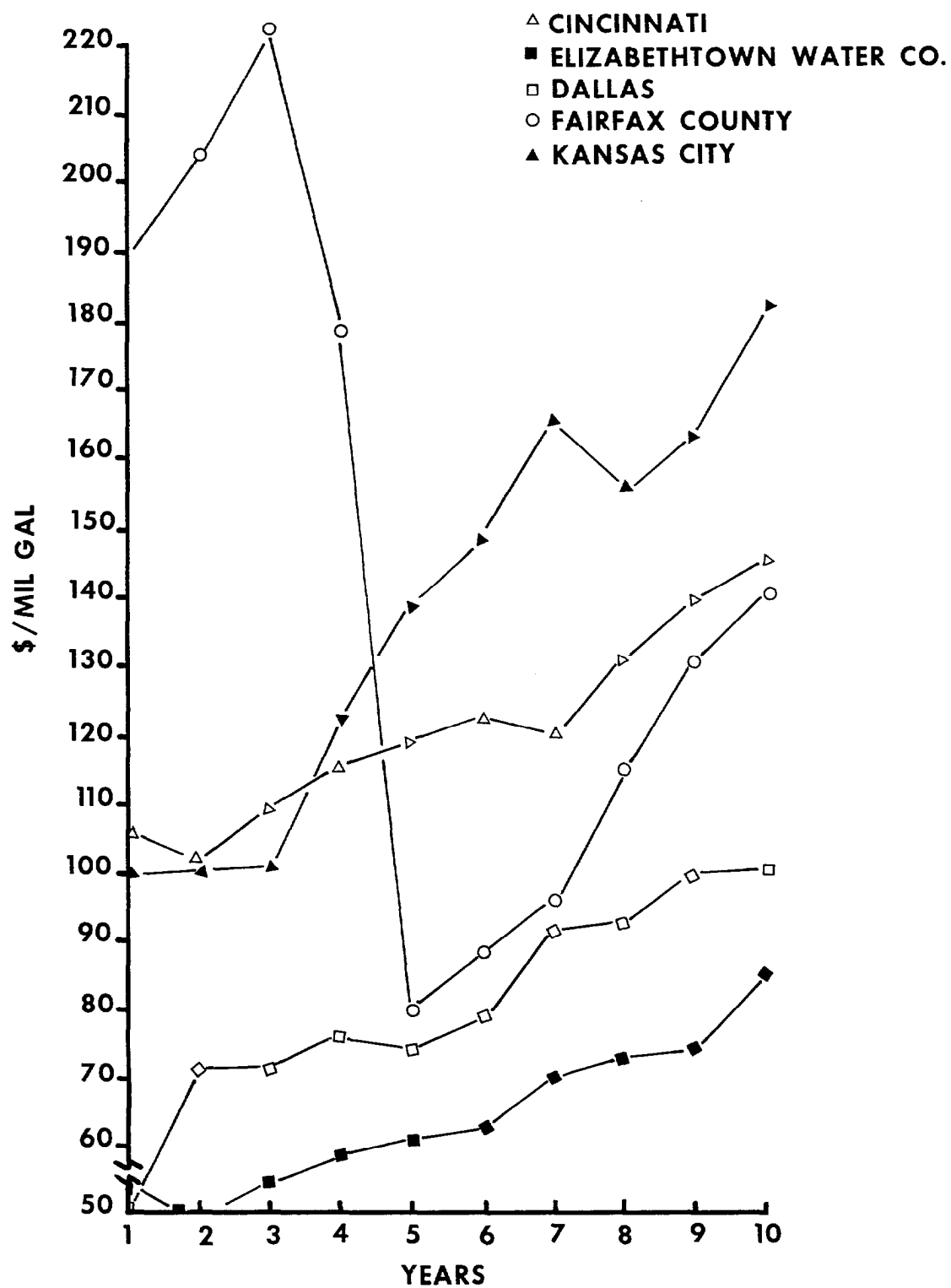


FIG. 58 PAYROLL/MIL GAL FOR FIVE UTILITIES

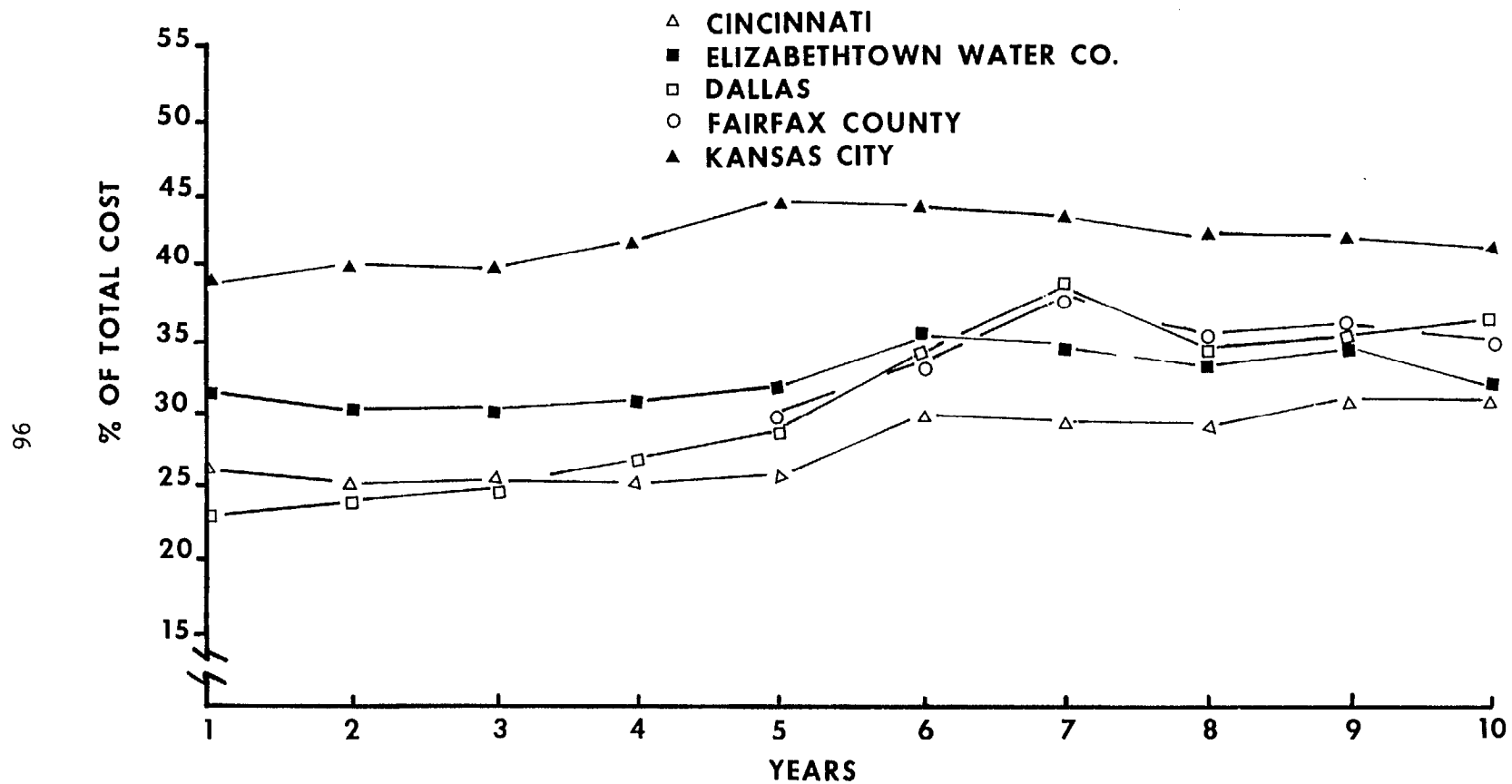


FIG. 59 SUPPORT SERVICES COST AS A PERCENT OF TOTAL OPERATING COSTS FOR FIVE UTILITIES

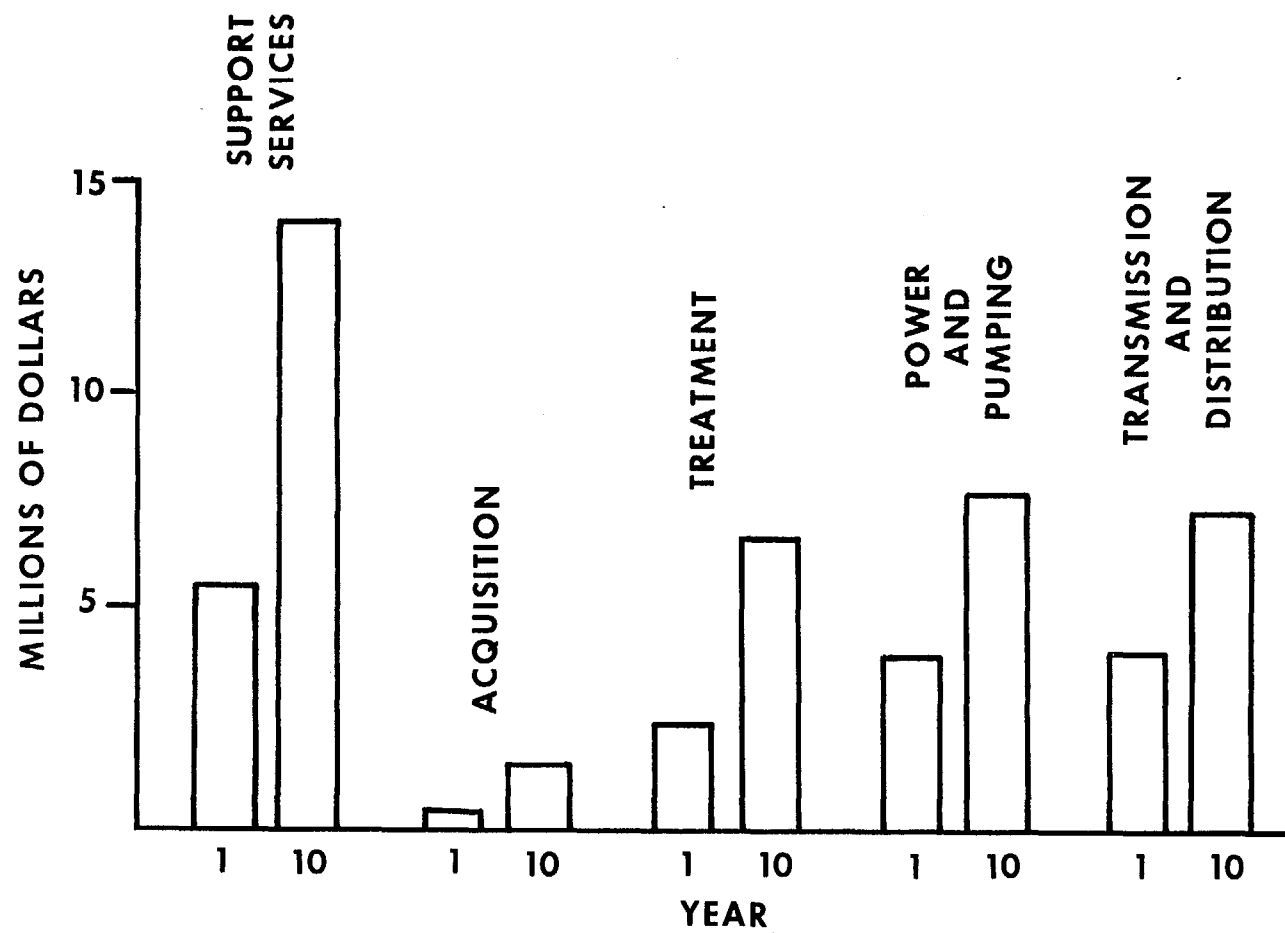


FIG.60 AVERAGE OPERATING COSTS FOR FIVE UTILITIES: BY CATEGORY

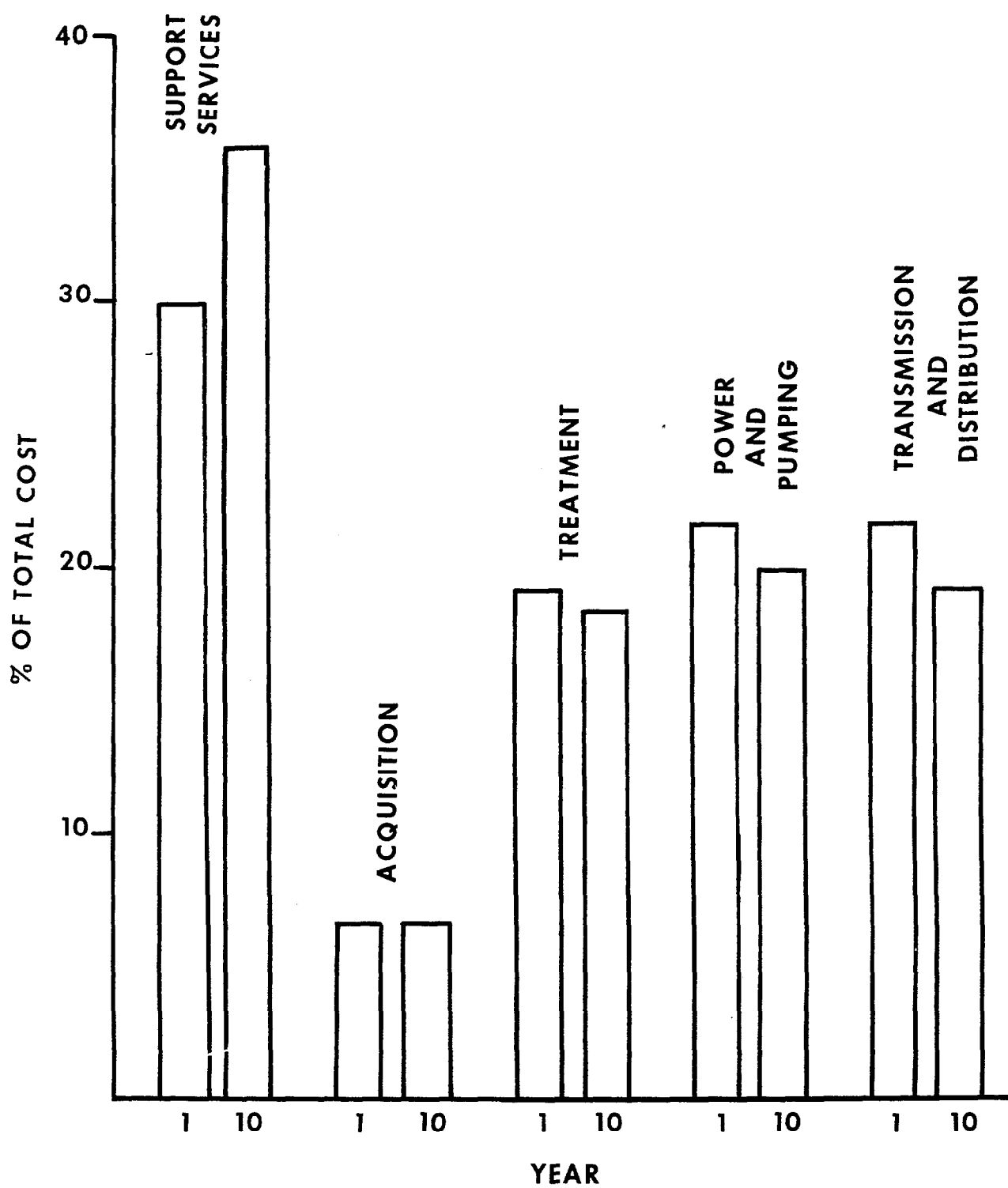


FIG. 61 UTILITY OPERATING COSTS: PERCENT OF TOTAL

same, and the other three categories (treatment, power and pumping, and transmission and distribution) decreased over the 10-year period.

### Summary of Results

As the data from these five utilities show, water supply costs are increasing as a result of labor and material cost increases. A moderating effect is due to increased productivity. Many of the increases are related to increased demand for water. The following section analyzes these costs in aggregate.

## SECTION 6

### AGGREGATE ANALYSIS

As the previous limited data analysis shows, certain key variables exhibit trends that can and should be analyzed. Therefore, averages of the data from all 12 utilities for specific variables have been constructed. The variables considered are as follows: revenue-producing water in billions of gallons, total operating cost, total capital cost, interest paid/year, depreciation/year, support services, acquisition, treatment, power and pumping, distribution, chemical cost, man-hours, man-hours/mil gal, payroll, dollars/man-hour, unit operating costs, unit capital cost, and total unit cost for production of water.

Table 14 summarizes the average costs associated with operating and capital expenditures over the 10-year period for all the utilities studied. Average expenditures increased by 110% over the period, but unit costs increased by only 25%.

Figure 62 shows the average revenue-producing water over the 10-year period. There has been a continuous upward trend in revenue-producing water, increasing from 23 billion gallons in 1965 to 32.1 billion gallons in 1974.

Figure 63 shows that the average operating expenditures have increased more rapidly than have capital expenditures. Operating costs increased by 127%, while capital costs increased by 78%.

Figure 64 shows the increases that have taken place in support services, acquisition, and treatment costs. Figure 65 shows the cost increases for transmission and distribution, and power and pumping over the period of analysis. Support services costs are obviously increasing at a much faster rate than other categories, although the increases in cost for power and pumping from 1972 through 1974 have been dramatic.

Figure 66 shows the increases over time for energy and chemical costs, and Figure 67 shows the same variables versus revenue-producing water. The relationship assumed in these two figures is linear, but it can be seen that energy costs are going up at a nearly exponential rate in recent years. Energy costs are increasing faster than chemical costs. Because support services is labor intensive, it is worthwhile to examine the labor portion of the costs. Manpower costs and labor productivity are therefore summarized in Table 15. The relationship between payroll and operating costs is shown in Figure 68. Figure 69 shows the relationship between labor wage rate and



TABLE 14. AVERAGE OPERATING AND CAPITAL COSTS FOR ALL FIVE UTILITIES OVER THE 10-YEAR STUDY PERIOD

Item	Years									
	1	2	3	4	5	6	7	8	9	10
OPERATING COSTS:										
Support services:										
\$, in millions	1.126	1.198	1.474	1.560	1.837	2.031	2.268	2.437	2.705	3.127
% of total	26.0	26.4	29.7	30.2	31.6	32.4	31.6	31.5	31.7	31.1
\$/mil gal	55.29	54.60	62.51	61.89	71.66	76.19	79.35	83.49	91.72	89.98
Acquisition:										
\$, in millions	0.981	1.007	0.978	1.062	1.231	1.289	1.537	1.770	1.990	2.356
% of total	22.7	22.2	19.7	20.6	21.2	20.5	21.4	22.9	23.3	23.5
\$/mil gal	48.27	45.91	41.46	42.22	48.08	48.20	53.75	60.69	67.42	67.43
Treatment:										
\$, in millions	0.539	0.577	0.617	0.630	0.701	0.783	1.013	0.913	0.998	1.212
% of total	12.5	12.7	12.4	12.2	12.1	12.5	14.1	11.8	11.7	12.1
\$/mil gal	26.58	26.27	26.10	25.0	27.44	29.39	35.41	29.63	33.85	35.01
Power and pumping:										
\$, in millions	0.789	0.830	0.922	0.870	0.933	0.955	1.042	1.172	1.294	1.805
% of total	18.2	18.3	18.5	16.8	16.1	15.2	14.5	15.2	15.2	18.0
\$/mil gal	38.70	37.85	38.94	34.43	36.51	35.74	36.42	40.29	43.98	52.08
Transmission and distribution:										
\$, in millions	0.890	0.927	0.978	1.044	1.108	1.213	1.320	1.439	1.548	1.541
% of total	20.6	20.4	19.7	20.2	19.1	19.3	18.4	18.6	18.1	15.3
\$/mil gal	43.81	42.19	41.46	41.40	43.32	45.38	46.21	49.30	52.37	44.27
Total operating cost:										
\$, in millions	4.074	4.272	4.579	5.030	5.830	6.285	6.934	7.593	8.431	9.262
\$/mil gal	212.65	206.82	210.47	204.95	226.78	235.14	251.15	265.04	289.34	286.95

TABLE 14 (Continued). AVERAGE OPERATING AND CAPITAL COSTS FOR ALL FIVE UTILITIES OVER THE 10-YEAR STUDY PERIOD

Item	Years									
	1	2	3	4	5	6	7	8	9	10
CAPITAL COSTS:										
Depreciation (\$, in millions)	1.241	1.296	1.430	1.547	1.604	1.661	1.693	1.828	1.904	2.145
Interest (\$, in millions)	0.996	0.920	0.948	1.286	1.267	1.428	1.411	1.488	1.707	1.848
Total capital costs (\$, in millions)	2.238	2.217	2.378	2.833	2.871	3.090	3.104	3.316	3.612	3.993
TOTAL OPERATING AND CAPITAL COSTS:										
\$, in millions	6.313	6.490	6.958	7.864	8.702	9.375	10.039	10.915	12.044	13.256
\$/mil gal	332.88	322.45	328.39	327.37	340.26	354.23	370.57	387.88	425.93	416.74

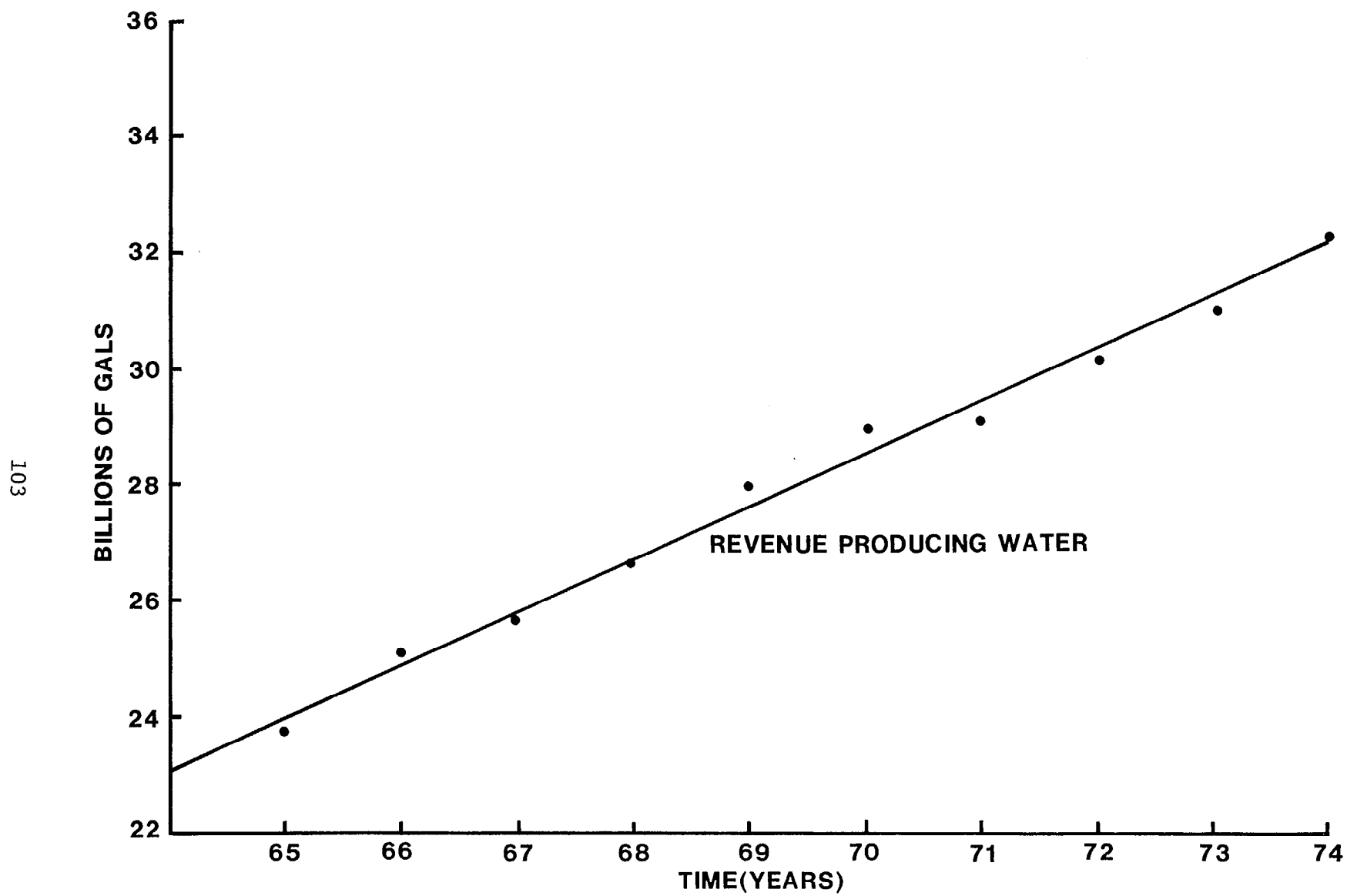


FIG. 62 AVERAGE REVENUE PRODUCING WATER

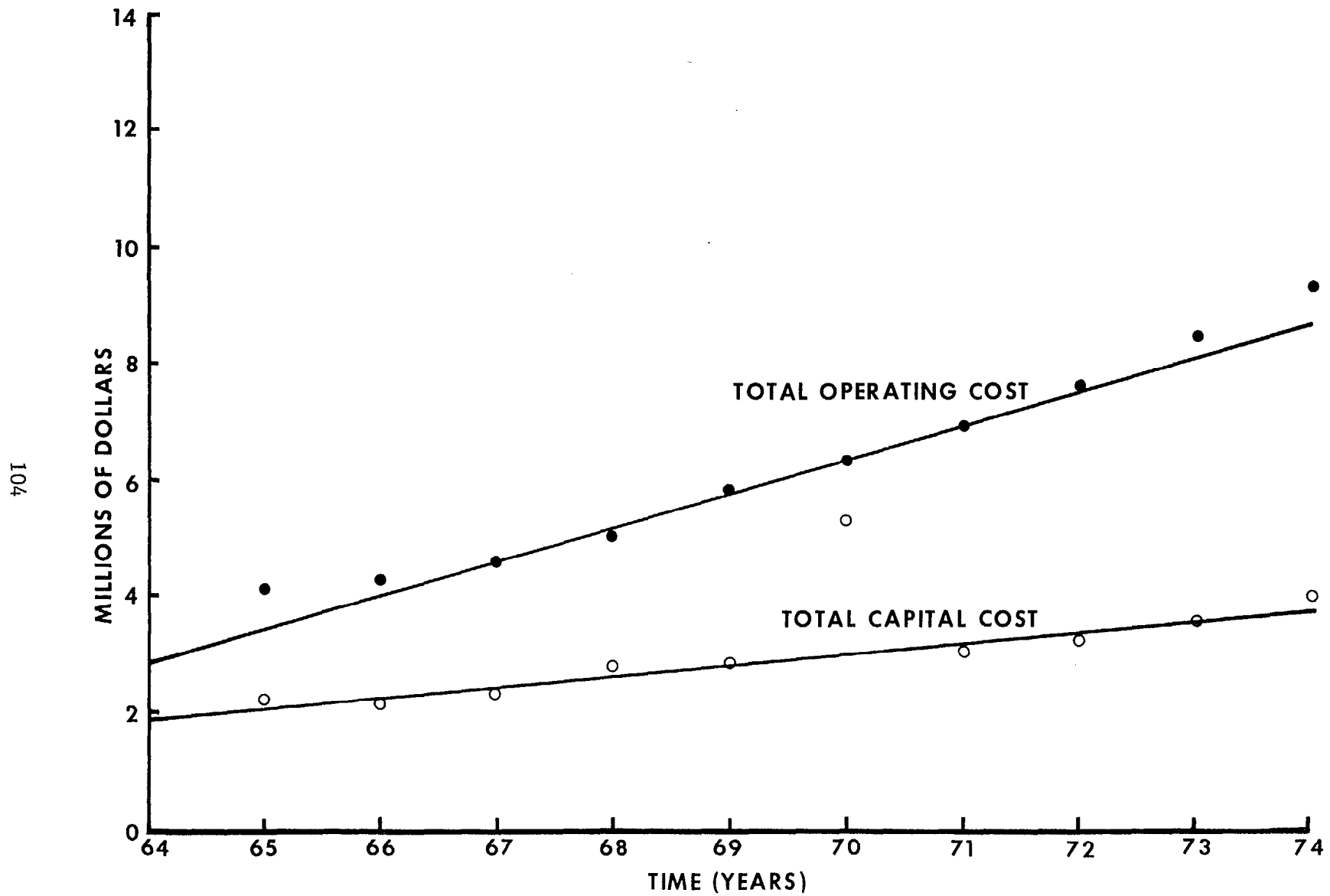


FIG. 63 AVERAGE TOTAL OPERATING AND CAPITAL EXPENDITURES

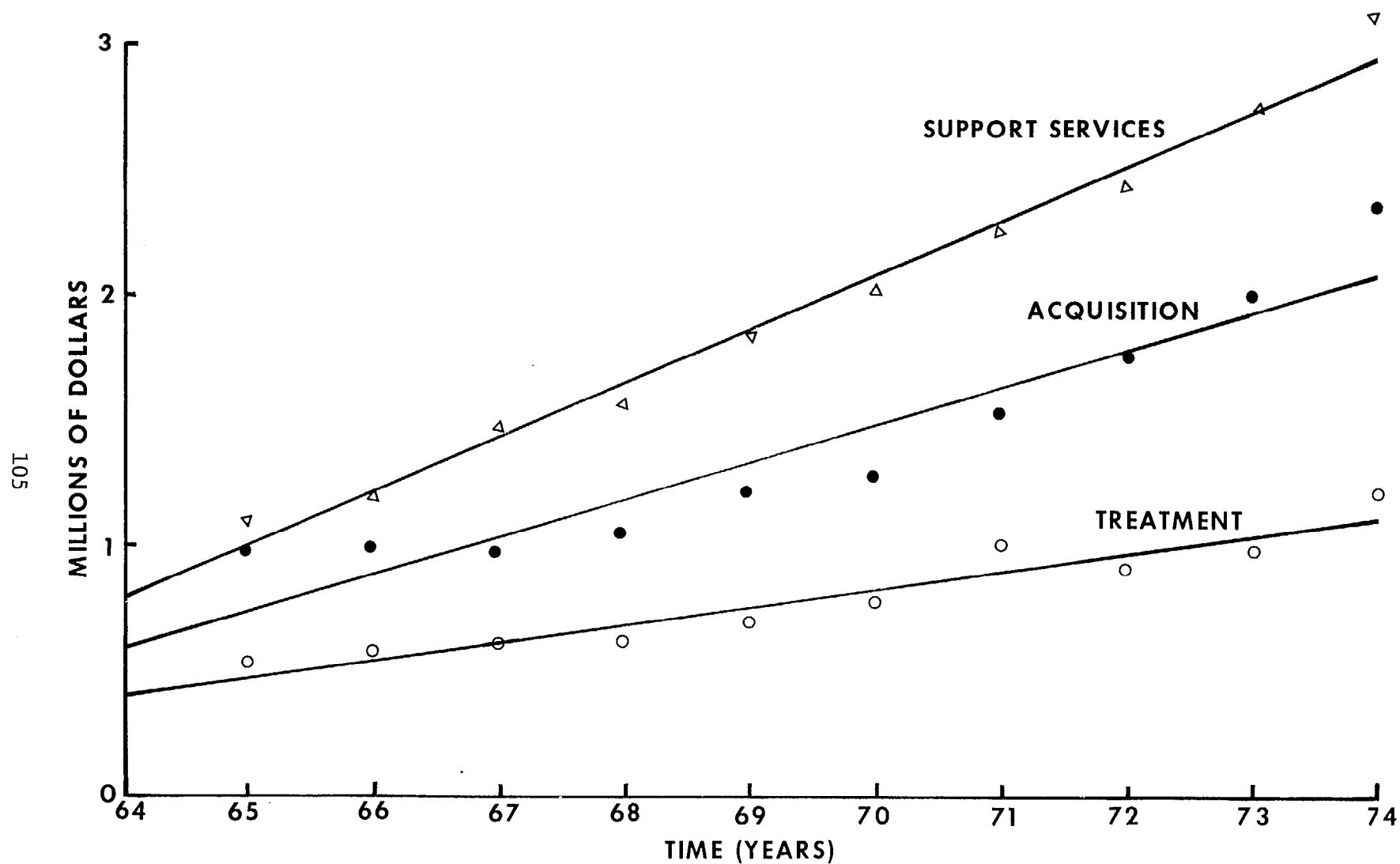


FIG. 64 AVERAGE OPERATING EXPENDITURES FOR SUPPORT SERVICES, ACQUISITION, AND TREATMENT

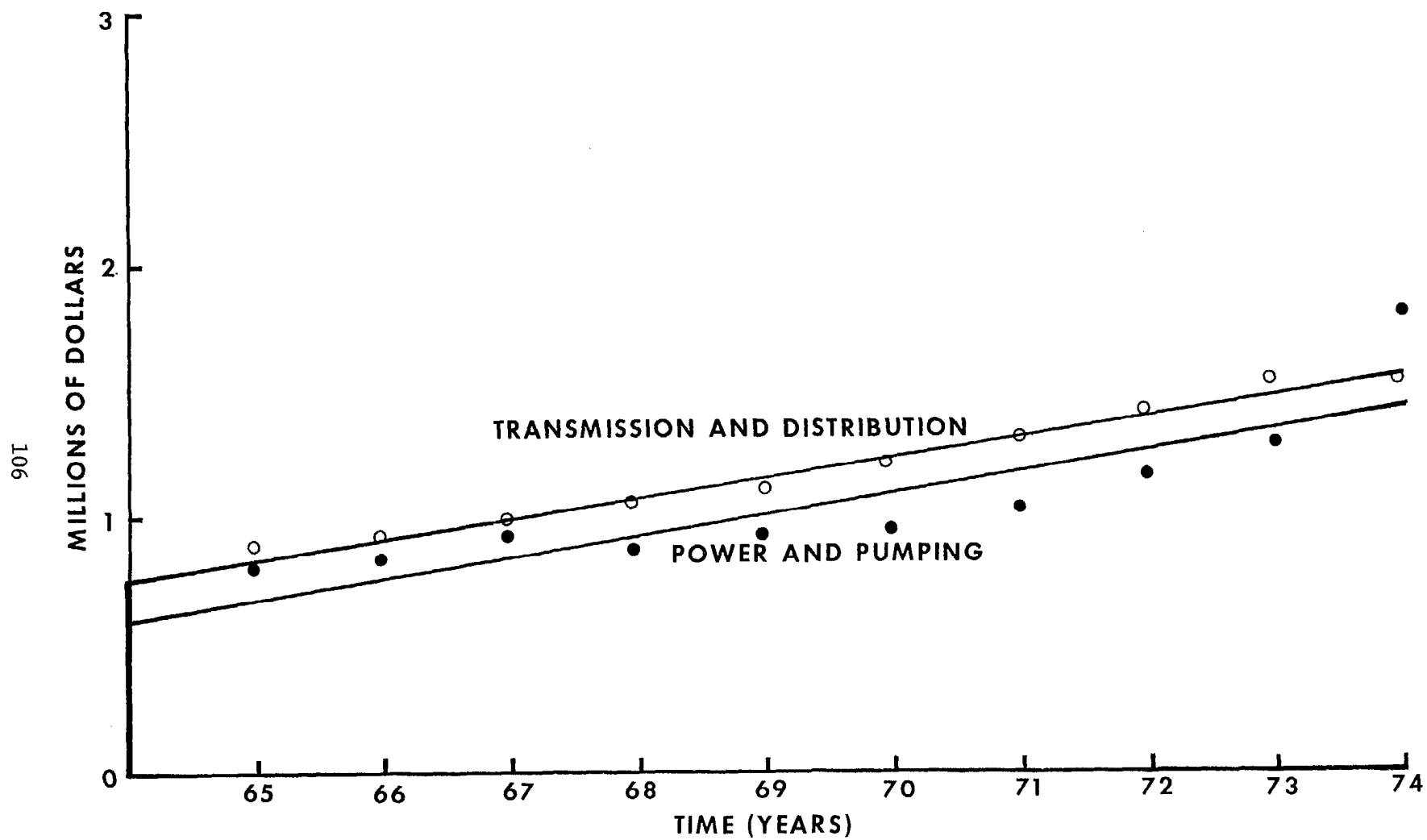


FIG. 65 AVERAGE OPERATING EXPENDITURES FOR TRANSMISSION AND DISTRIBUTION AND POWER AND PUMPING

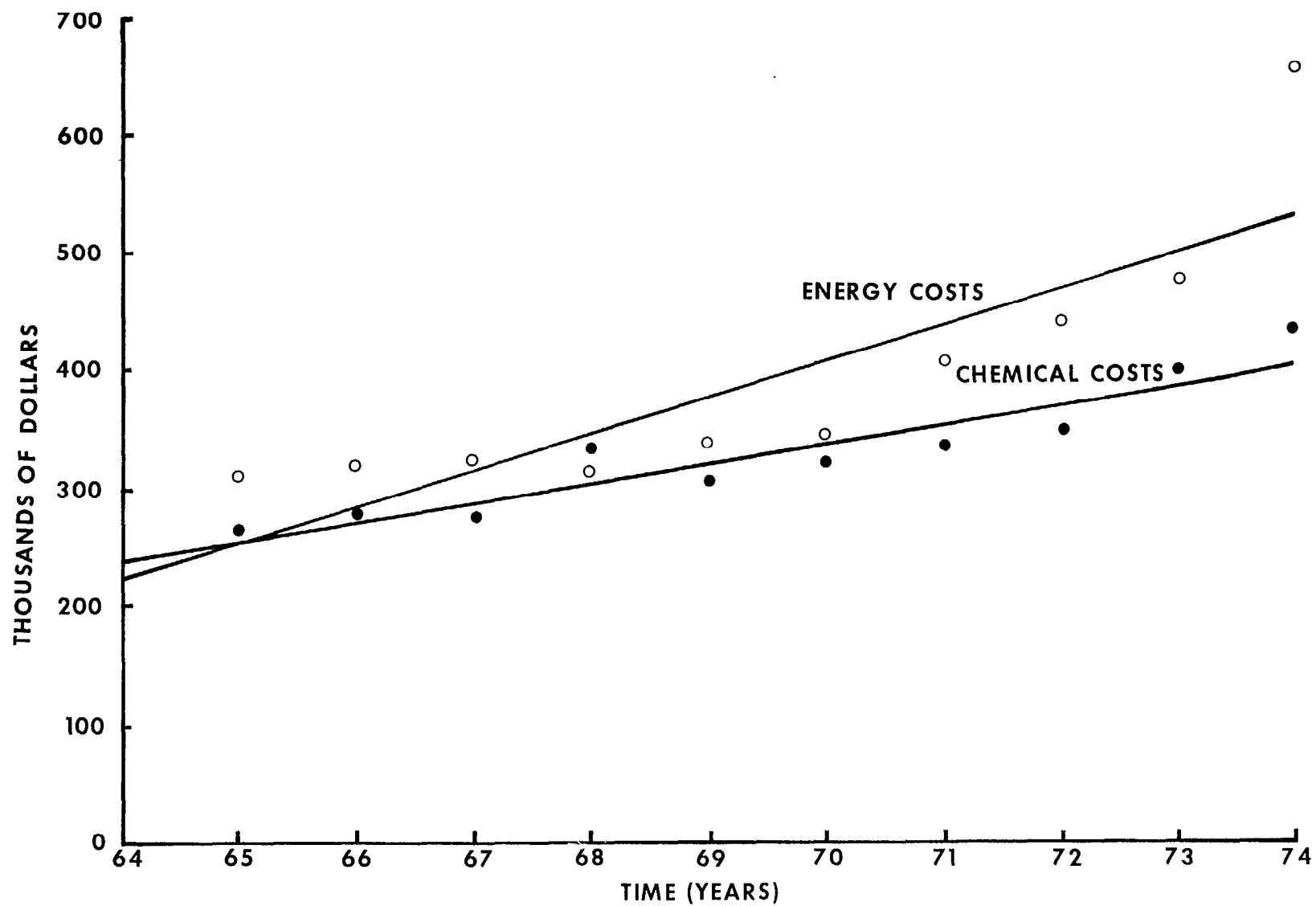


FIG. 66 AVERAGE OPERATING EXPENDITURES FOR ENERGY AND CHEMICALS VERSUS TIME

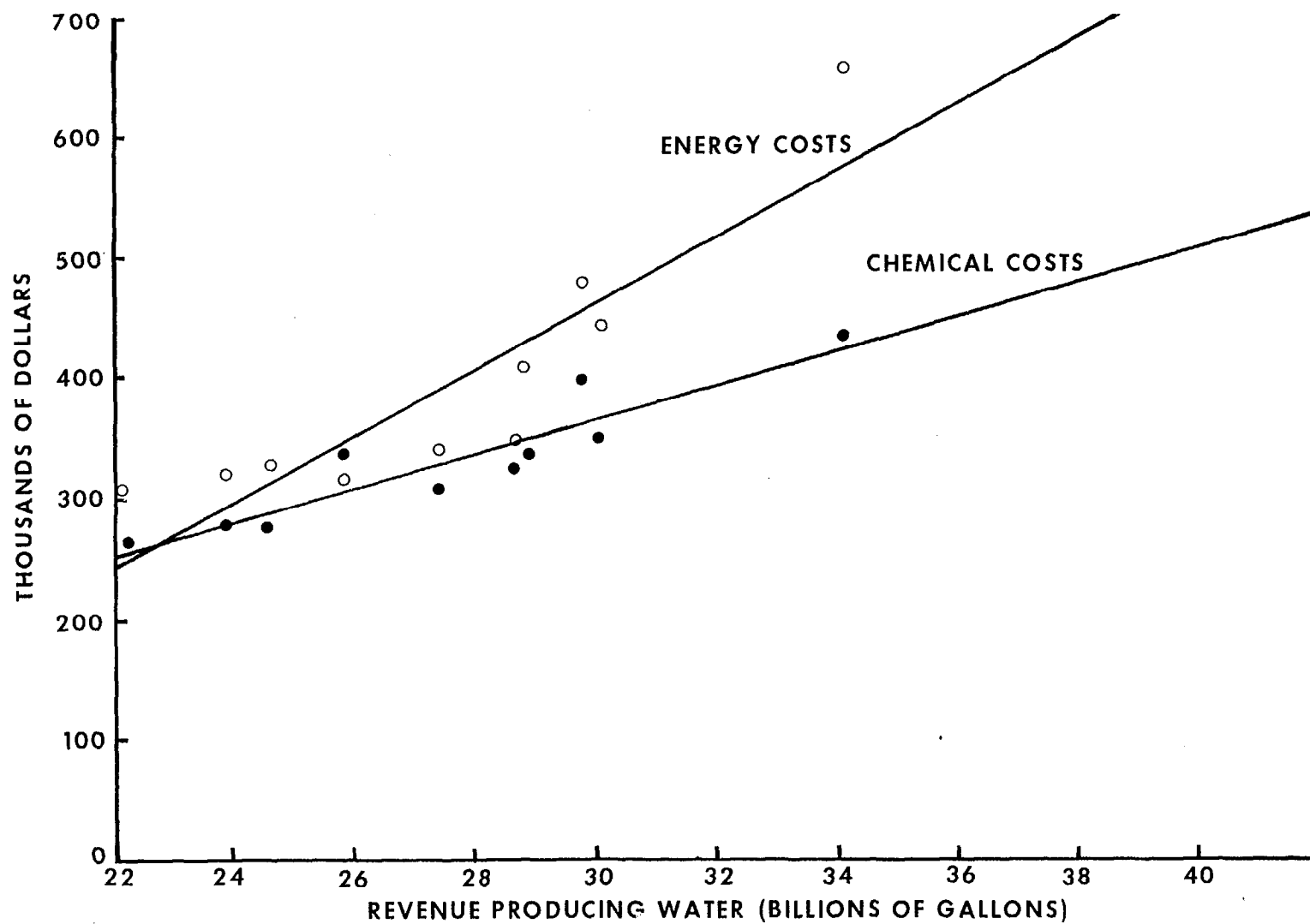


FIG. 67 AVERAGE OPERATING EXPENDITURES FOR ENERGY AND CHEMICALS VERSUS REVENUE PRODUCING WATER



TABLE 15. MANPOWER COSTS AND PRODUCTIVITY

Cost item	Year									
	1	2	3	4	5	6	7	8	9	10
Total payroll	1,713,806	1,825,217	2,006,525	2,237,453	2,525,527	2,724,751	3,040,661	3,392,529	3,665,588	3,857,361
Total hours on payroll	659,156	683,602	716,616	743,340	756,145	754,778	787,736	794,507	816,389	813,789
Metered consumption (mil gal)	22,193	23,930	24,619	25,864	27,456	28,736	28,904	30,159	29,857	34,169
Total payroll metered (\$/mil gal)	77.22	76.27	81.50	86.51	91.98	94.82	105.20	112.49	122.77	112.89
Total hours metered consumption (hrs/mil gal)	33.75	32.50	30.42	29.85	31.17	29.70	30.32	29.83	30.50	28.32
Average Cost per man-hour	2.60	2.67	2.80	3.01	3.34	3.61	3.86	4.27	4.49	4.74
Capital/labor cost ratio	1.31	1.21	1.18	1.27	1.14	1.13	1.02	0.98	0.99	1.04

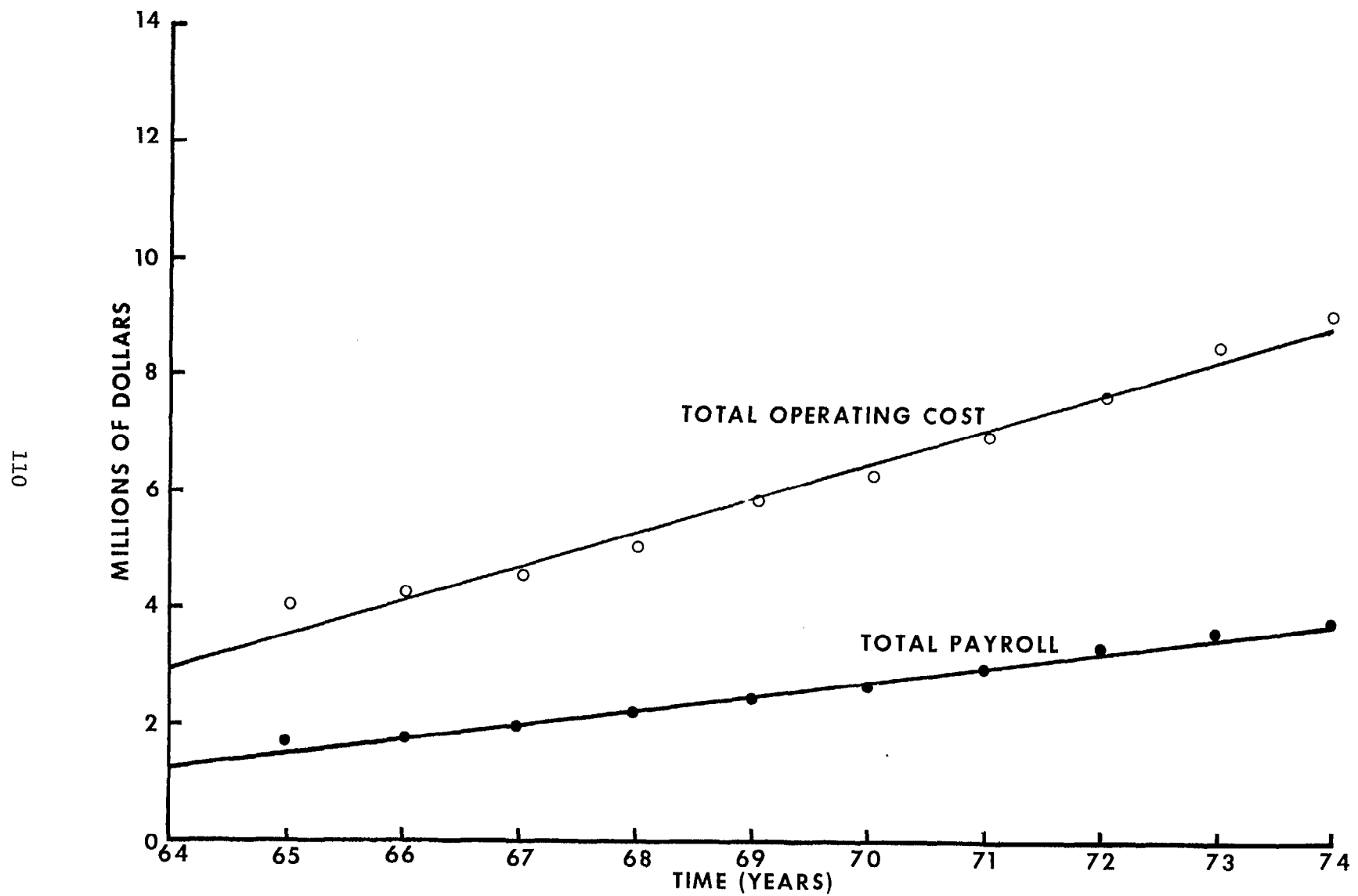


FIG. 68 AVERAGE EXPENDITURE FOR OPERATING AND PAYROLL COSTS

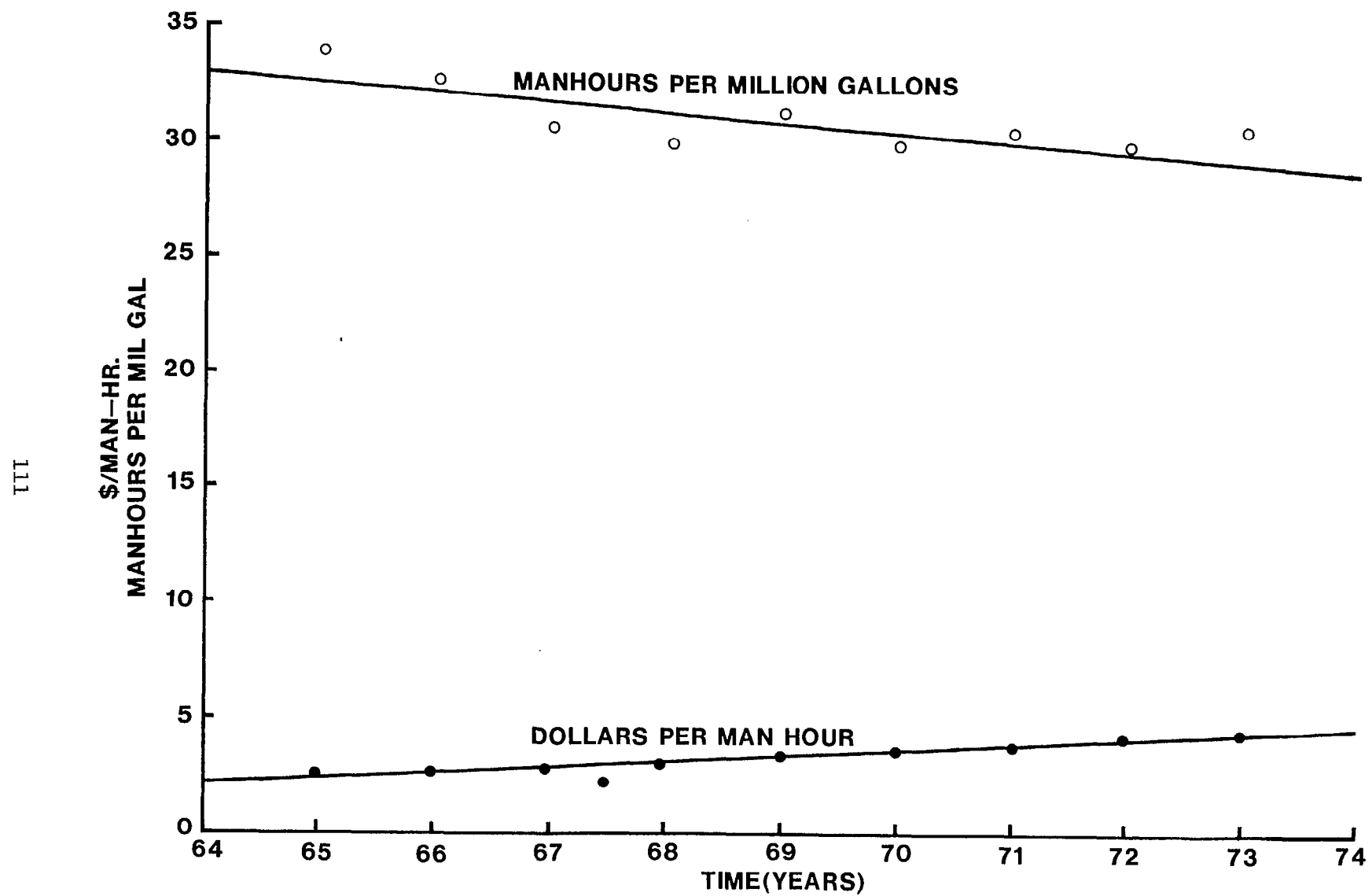


FIG. 69 MANHOURS PER MIL GAL AND DOLLARS PER MAN HOUR

productivity. Figures 70 and 71 summarize unit operating and capital costs as they relate to time and revenue-producing water.

Figures 72 and 73 show average unit costs for the five utilities versus time and revenue-producing water, both historical and corrected by the CPI, assuming 1965 as the base year.

Table 16 contains the best fit equation for some of the major items mentioned in this section. The relationship  $C = aQ^b e^{st}$  is used to show dependency of cost with both production quantity (Q) and time ( $e^{st}$ ). By virtue of this analysis, one can see the way in which time influences the cost of some of these cost categories.

Figures 63 through 73 and Tables 14, 15, and 16 show that water costs are affected by the same inflationary costs as the general economy, but that economies of scale and increases in productivity have managed to keep unit costs down. The unit cost of water has actually decreased when corrected by the CPI.

Figure 68 and Table 15 show that payroll costs account for approximately 42% of the total operating cost for the 12 utilities. Labor accounts for only 27% of the operating cost in San Diego so that when San Diego figures are removed, labor costs are 52% of the operating costs for the remaining 11 utilities.

Another factor not included in total payroll is fringe benefits. Using data from all 12 utilities, it is estimated that fringe benefits would add approximately 20% to the total payroll costs. Therefore, labor related costs might represent between 50% and 60% of the operating and maintenance costs.

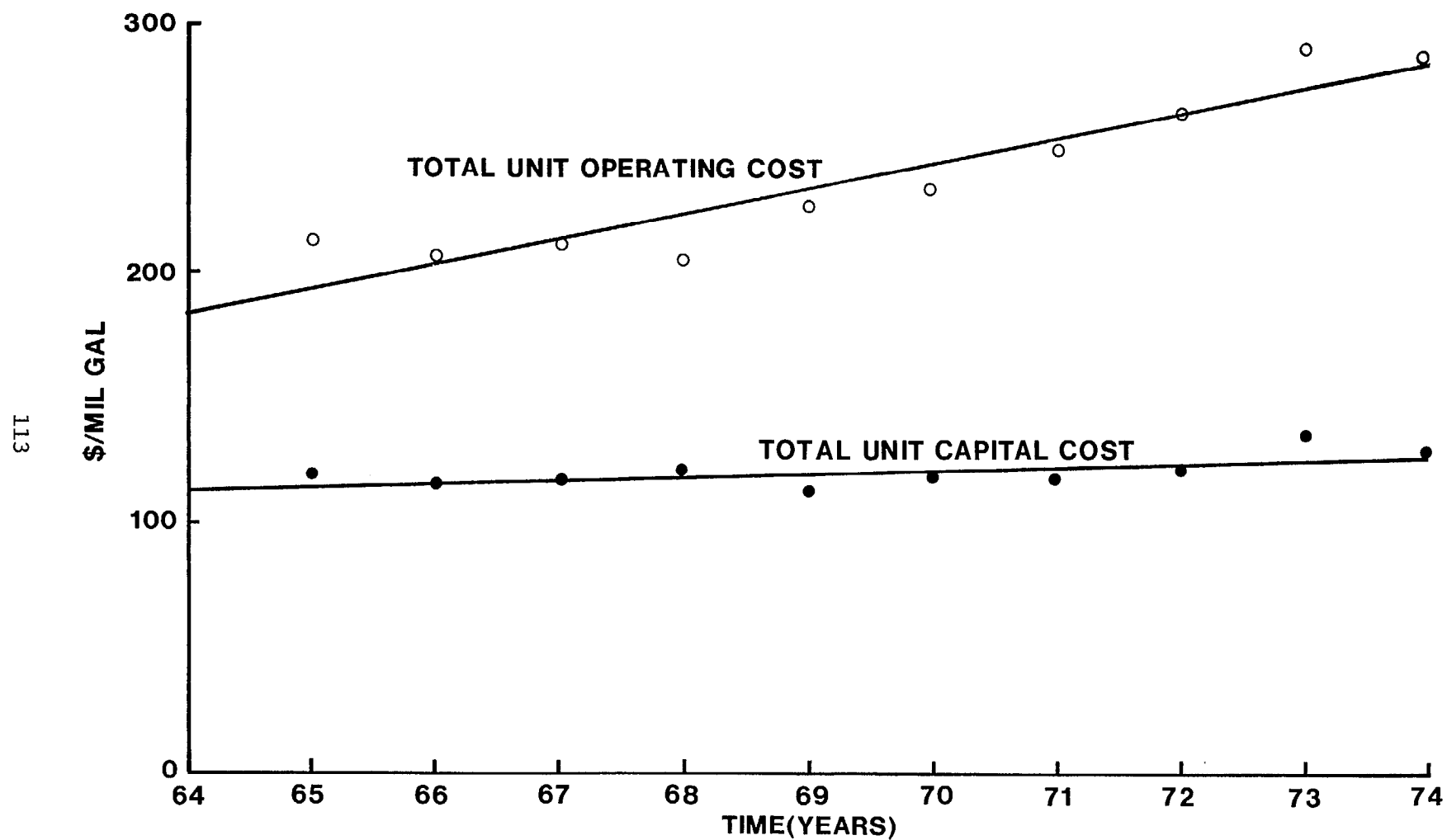


FIG. 70 AVERAGE TOTAL UNIT OPERATING AND CAPITAL COSTS VERSUS TIME

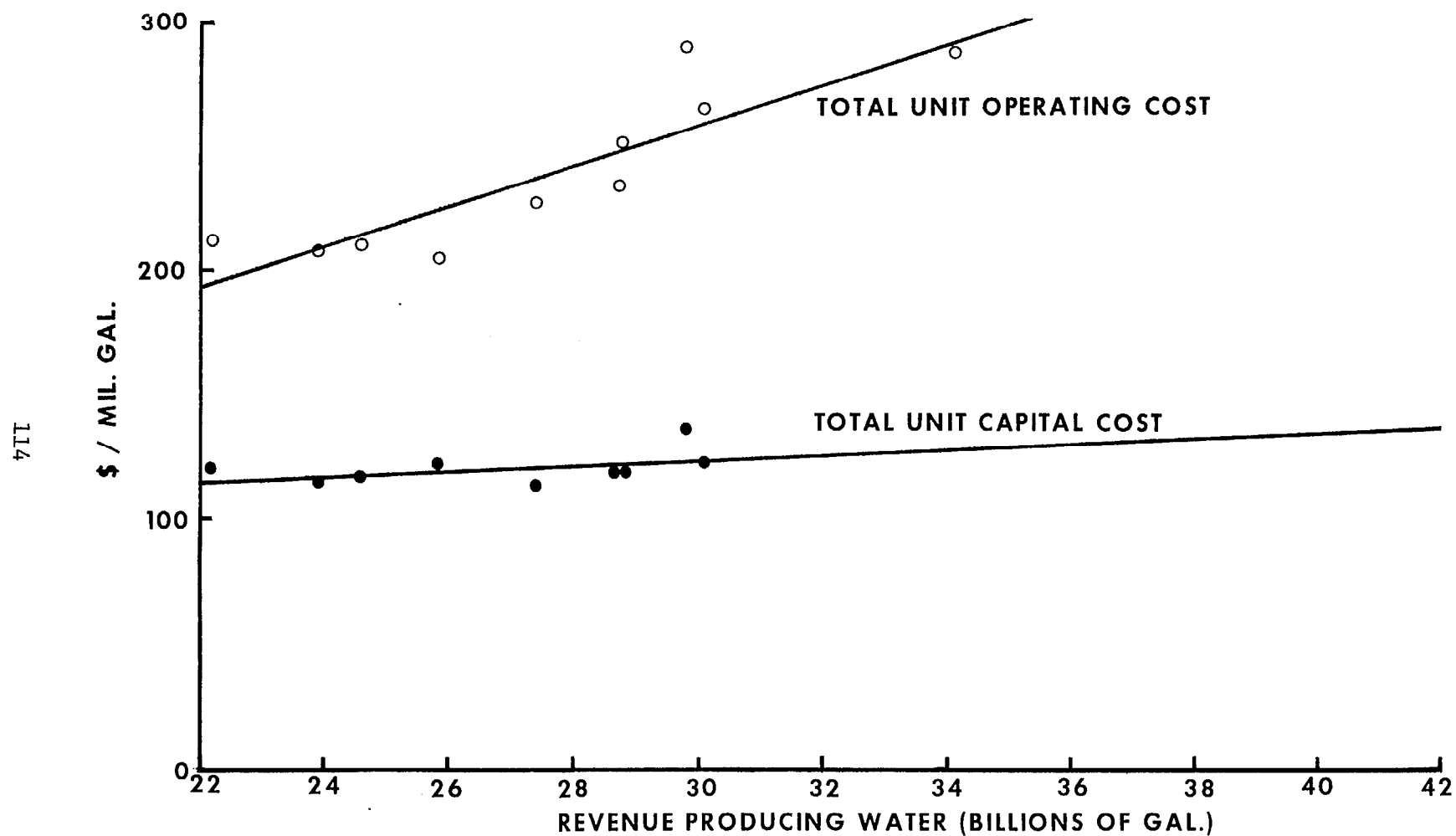


FIG. 71 AVERAGE TOTAL UNIT OPERATING, AND CAPITAL COST VERSUS REVENUE PRODUCING WATER

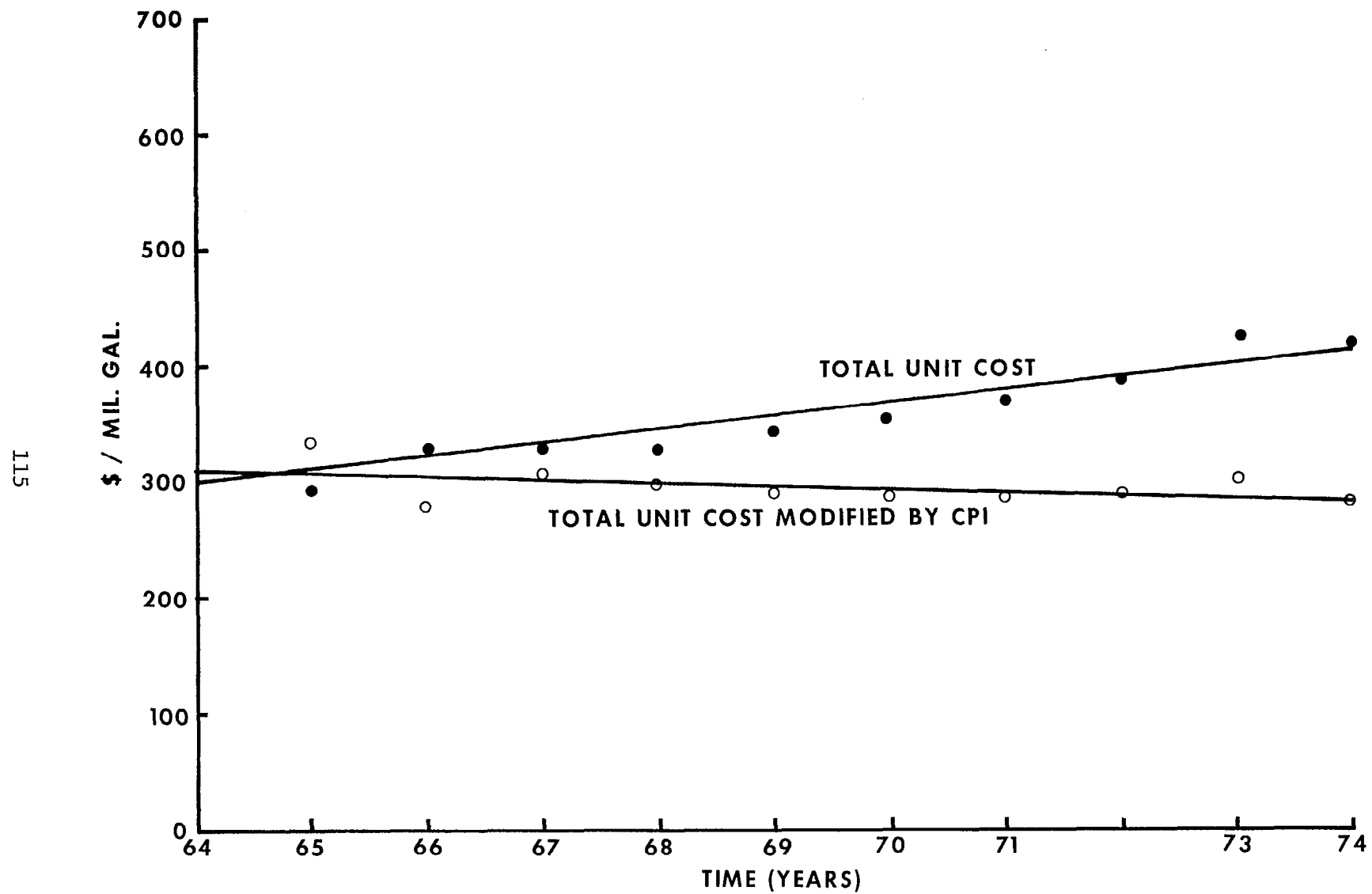


FIG. 72 AVERAGE TOTAL UNIT COST VERSUS TIME: HISTORICAL AND MODIFIED

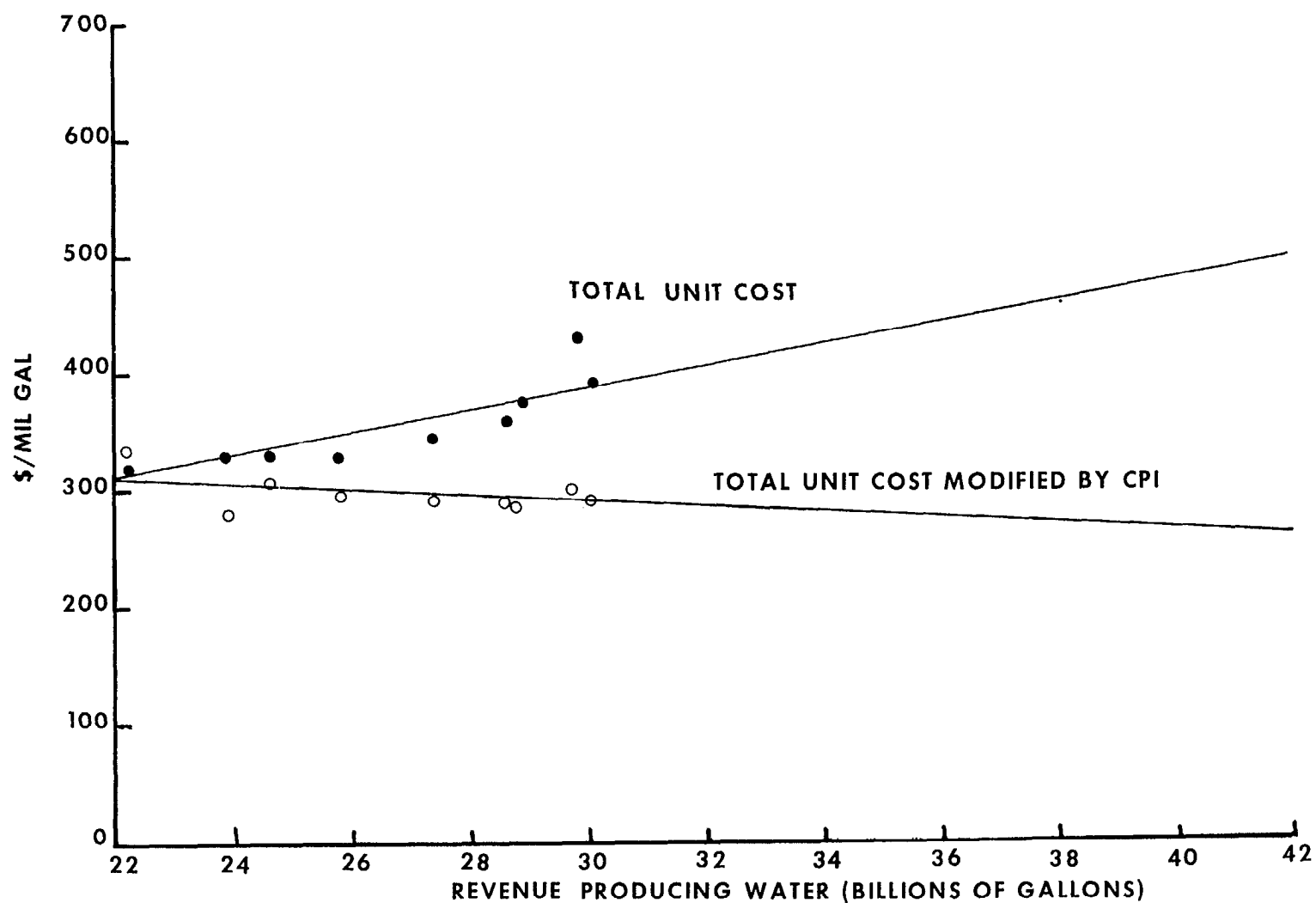


FIG. 73 AVERAGE TOTAL UNIT COST VERSUS REVENUE PRODUCING WATER: HISTORICAL AND MODIFIED



TABLE 16. O &amp; M AND CAPITAL COSTS FOR ALL UTILITIES

Item	Operating Cost $C = aQ^b e^{st}$				Capital Cost $C = aQ^b e^{st}$			
	a	b	s	$r^2$	a	b	s	$r^2$
Acquisition	1.4	1.23	0.043	.64	$2 \times 10^{-8}$	2.94	0.000	0.67
Treatment	2379.1	0.52	0.063	0.56	32.8	0.82	0.066	0.40
Transmission and Distribution	211.0	0.82	0.052	0.92	178.0	0.89	0.036	0.86
Support Services	78.43	0.95	0.073	.95	24.35	0.88	0.044	0.66
Total	360.4	0.91	0.056	0.93	193.8	0.91	0.043	0.86

\* t is relative time, starting with year 1 as the first year of data.

Q is revenue-producing water in mil gal per year.

C is annualized cost in dollars (exclusive of interest).

## SECTION 7

### MODEL DEVELOPMENT

#### Annual Operating and Capital Costs

With data developed in the previous sections, a set of equations can be derived that relates a selected set of variables to the cost of water supply. The first relationship to be developed using regression analysis is as follows:

$$AOC = 20.13 (D_{mh})^{0.69} (M_{mg})^{0.54} Q^{0.96} \quad (r^2 = 0.96) \quad (1)$$

where AOC = annual operating cost

$D_{mh}$  = \$/man-hour

$M_{mg}$  = man-hr/mil gal

$Q$  = revenue-producing water for a given year in mil gal/year

Equation 1 demonstrates the important relationship that exists between the variables that describe labor cost (\$/man-hr), productivity (man-hr/mil gal), revenue-producing water, and annual operating cost (AOC). As can be seen from Equation 1, AOC increases nearly linearly with respect to increases in revenue-producing water if labor cost and productivity are constant. The previous section indicates that labor cost has been rising at a faster rate than productivity, but the increase in productivity (decreasing man-hr/mil gal) has tended to keep operating costs down. The partial derivatives for Equation 1 with respect to the independent variables are as follows:

$$\frac{\partial AOC}{\partial D_{mh}} = 13.89 (D_{mh})^{-0.31} (M_{mg})^{0.54} (Q)^{0.96} \quad (2)$$

$$\frac{\partial AOC}{\partial M_{mg}} = 10.87 (D_{mh})^{0.69} (M_{mg})^{-0.46} Q^{0.96} \quad (3)$$

$$\frac{\partial AOC}{\partial Q} = 19.32 (D_{mh})^{0.69} (M_{mg})^{0.54} Q^{-0.04} \quad (4)$$

Equations 2, 3, and 4 demonstrate the relative changes in cost that would take place with changes in labor cost, productivity, and revenue-producing water, assuming all other variables are constant.

Taking the natural log of Equation 1 yields:

$$\ln AOC = 3.00 + 0.69 \ln D_{mh} + 0.54 \ln M_{mg} + 0.96 \ln Q \quad (5)$$

It is possible to study the effect of holding the rate of change for Equation 5 constant.

$$\text{For example, if } \partial(\ln AOC)/\partial(\ln D_{mh}) = 0 \quad (6)$$

$$\text{then } \frac{\partial(\ln M_{mg})}{\partial(\ln D_{mh})} = -1.28 \quad (7)$$

Therefore, if  $D_{mh}$  increases, then  $M_{mg}$  must decrease for Equation 6 to hold.

If  $(M_{mg}^{(1)}, D_{mh}^{(1)})$  and  $(M_{mg}^{(2)}, D_{mh}^{(2)})$  represent two sets of data points,

$$\text{then } M_{mg}^{(1)}/M_{mg}^{(2)} = (D_{mh}^{(1)}/D_{mh}^{(2)})^{-1.28} \quad (8)$$

If  $M_{mg}^{(1)} = 28 \text{ man-hours/mil gal}$  and  $D_{mh}^{(1)} = \$4.8/\text{hour}$  and if  $D_{mh}^{(2)}$

$= \$9.6/\text{hour}$ , then the following relationship must hold:

$$M_{mg}^{(2)} = (M_{mg}^{(1)}) \frac{(D_{mh}^{(1)})}{(D_{mh}^{(2)})} \quad (9)$$

$$M_{mg}^{(2)} = 11.5 \frac{\text{man-hours}}{\text{mil gal}}$$

As shown by Equation 9, the productivity must more than double for the cost to stay constant. Similar relationships can be derived for the other variables using partial derivatives. These partials are summarized in Table 17.

TABLE 17. PARTIAL DERIVATIVES FOR EQUATION 5

<div style="display: inline-block; transform: rotate(-45deg);"> <math>x =</math>  <math>y =</math> </div>	$\partial x / \partial y$		
	$\ln D_{mh}$	$\ln M_{mg}$	$\ln Q$
$\ln D_{mh}$	---	- 1.28	- 0.72
$\ln M_{mg}$	- 0.78	---	- 0.56
$\ln Q$	- 1.39	- 1.78	---

The Annual Capital Cost is given by the following relationship:

$$ACC = 25.7 (D/Q)^{0.74} Q^{0.84} \quad (r^2 = 0.92) \quad (10)$$

where ACC = Annual capital cost

D = Annual depreciation

Q = Annual revenue-producing water

If, in Equation 10,  $D/Q = U$ , then the natural log transform is as follows:

$$\ln ACC = 3.25 + 0.74 \ln U + 0.84 \ln Q \quad (11)$$

The partials for Equation 11 are shown in Table 18.